Chapter 3
Risk Assessment

This chapter will describe the risks facing Clark County from each of eight hazards, elaborating upon the hazard definition, vulnerabilities and probable event scenarios. Taken as a whole, this chapter assesses the risk Clark County is likely to experience from hazard events.

These hazards were identified through an extensive process that utilized input from the Clark County All Hazard Mitigation Plan Steering Committee members and hazard experts, public input, past disaster history, current Flood Insurance Rate Maps and data about current flood insurance holders, Clark County's GIS database (soils maps, critical infrastructure maps, slopes maps, land uses, etc.) and Clark County's Hazard Inventory and Vulnerability Assessment (2000).

Risk was defined through the following process, which is reflected in the organization of Chapter 3:

1. Identify and profile each hazard
2. Determine exposure to each hazard
3. Assess the vulnerability of exposed infrastructure and facilities
4. Identify existing capabilities
5. Visualize future expected losses through building a most probable case scenario.

Several hazards were shown not to affect Clark County and were therefore not included in this risk assessment. Inundation from dam failure was not considered because during the last Federal Energy Regulatory Commission (FERC) re-licensing procedure, Clark County dams were assessed as stable and inundation zones were shown to mirror floodplains. Additionally, several hazards are not applicable to Clark County, such as tsunamis and hurricanes, and were not included in this risk assessment.

Table 3.1 summarizes the hazards described in this chapter as well as how and why they were identified.

Hazard	*How identified*	*Why identified*
Earthquakes Chapter 3a	HIVA, review of past disaster events, input from Washington State Department of Natural Resources and other seismology experts.	Earthquakes have been determined to be a likely occurrence, and could potentially cause severe damage in the region.
Floods Chapter 3b	HIVA, review of past disaster events, FIRM maps, input from Public Works and Planning Departments.	Floods have caused damage (personal and property) and evacuation situations in the past, and are likely to occur again in the future
Wildfire Chapter 3c	HIVA, review of past disaster events, input from fire districts and Washington Department of Ecology	Fires have caused property damage in the county in the past. The topography, biology, and climate of the county make future events likely. New development is occurring in fire-prone areas.
Severe Weather Chapter 3d	HIVA, review of past disaster events, input from emergency response personnel and steering committee.	Severe weather is a frequent occurrence in the county; the most recent federally declared disaster was a severe weather event. The secondary effects of severe weather (floods, landslides) can be severe and damaging.
Hazardous Materials Chapter 3f	HIVA, Several manufacturing companies utilize or produce hazardous materials in the county. Many hazardous materials are transported through the county by road, rail, or boat.	Hazardous materials releases have occurred at some locations in the county, and can cause sudden and severe damage to community health.
Landslides Chapter 3g	HIVA, Clark County GIS database of historic landslide areas and steep slopes, input from local officials	Landslides are a somewhat regular occurrence in the county. New development is occurring in areas of potential landslide hazard.
Volcanoes Chapter 3e	HIVA, review of past disaster events, input from USGS	There are several active volcanoes in counties bordering Clark.
Terrorism Chapter 3g	HIVA, Input from Terrorism Task Force members, police and fire representatives	Heightened sense of security since September, 2001

Table 3.1: Summary of Hazards in Clark County

Chapter 3a
Earthquakes

Definitions

Earthquake

An earthquake is the shaking of the ground caused by an abrupt shift of rock along a fracture in the earth such as a fault or a contact zone between tectonic plates. Earthquakes are measured in both magnitude and intensity.

Magnitude

Magnitude is the measure of the strength of an earthquake, and is typically measured by the Richter scale. As an estimate of energy, each whole number step in the magnitude scale corresponds to the release of about 31 times more energy than the amount associated with the preceding whole number value.

Intensity

Intensity is a measure of the effects of an earthquake. It is measured by the Mercalli scale and is expressed in Roman numerals.

Peak Ground Acceleration

A measure of the highest amplitude of ground-shaking that accompanies an earthquake, based on a percentage of the force of gravity.

Subduction Zone Earthquake

This type of quake occurs along two converging plates, attached to one another along their interface. When the interfaces between these two plates slips, a sudden, dramatic release of energy results, propagated along the entire fault line.

Crustal Earthquake

Crustal quakes occur at a depth of 5 to 10 miles beneath the earth's surface and are associated with fault movement within a surface plate.

Benihoff Earthquake

Sometimes called "deep quakes," these occur in the Pacific Northwest when the Juan de Fuca plate breaks up underneath the continental plate, approximately 30 miles beneath the earth's surface.

Liquefaction

Liquefaction is the complete failure of soils, occurring when soils lose shear strength and flow horizontally. It is most likely to occur in fine saturated fine grain sands and silts, which behave like viscous fluids when liquefaction occurs. This situation is extremely hazardous to development on the soils, and generally results in extreme property damage and threats to life and safety.

Background, Earthquake Events

Historically, there have been several earthquakes that have affected the Clark County area. Like most of the northwestern coast of the United States, the county is susceptible to Cascadia Subduction Zone events, which are generally major in scale. On January 26, 1700, an approximate magnitude 9 Cascadia Subduction Zone earthquake occurred. This earthquake was very damaging and inundated coastal areas from British Columbia to northern California and lowered coastal land elevations by as much as 6 feet.

Clark County has also been susceptible to shallow, crustal earthquakes. The 1872 earthquake in the North Cascades was the largest crustal earthquake in the recorded history of Washington and Oregon. It had an estimated magnitude of 7.4 and was followed by many aftershocks. In 1993, a magnitude 5.6 earthquake in the Willamette Valley of Oregon caused $28 million in damages, including damage to the Oregon State capital building in Salem. A pair of earthquakes near Klamath Falls, Oregon of magnitude 5.9 and 6.0 caused two fatalities and $7 million in damage.[1]

Benihoff or deep earthquakes have also moderately affected Clark County in the past. The two most damaging Benihoff earthquakes in Washington occurred in 1949 and 1965. The 1949 earthquake occurred near Olympia and had a magnitude of 7.1. The earthquake of 1965 occurred between Seattle and Tacoma with a magnitude of 6.5. These tend to be centered in the Puget Sound region and have little impact on Clark County.

More recently on February 28, 2001, the Nisqually earthquake, with a magnitude of 6.8, occurred northeast of Olympia, Washington. Most of the damage was concentrated in small-localized areas with poor site conditions and older construction in central Puget Sound. This earthquake caused minor damage in some areas of Clark County as well. Geologists have concluded that Benihoff earthquakes are a phenomenon centered in the Puget Sound basin and as such their epicenters are at a considerable distance from Clark County. Their impact on Clark County is expected to be minimal to moderate. Figure 3.1 displays the three different types of earthquakes discussed.

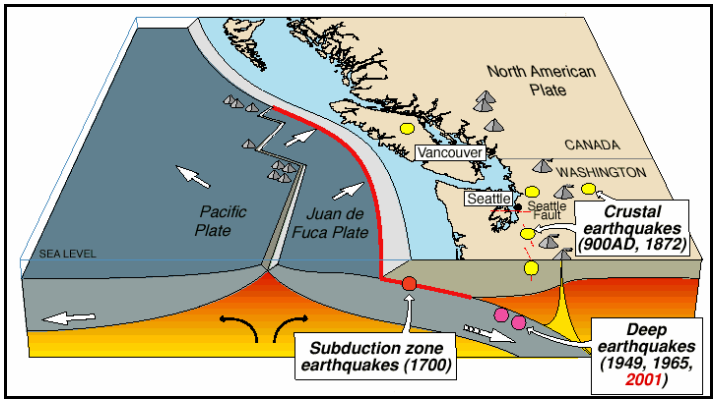

Figure 3.1: Earthquake Types

Earthquake Hazard in Clark County

The two main types of earthquakes that would affect Clark County include the Cascadia Subduction Zone and Portland Hills Fault Zone earthquakes. Surface ruptures from the known

faults within the northeastern portion of the county are assumed to be very remote. The Cascadia Subduction Zone includes the region of potential rupture formed by the overlap of the North American continent and the Pacific Ocean. The zone of contact covers approximately 140,000 square miles along the northwestern coast of the United States and British Columbia in Canada. The estimated width of the brittle, upper portion of this zone ranges from 40 kilometers off the coast of Washington tapering to a more consistent 10 kilometers along Oregon, northern California and northern Vancouver Island. The zone varies in depth from 5 kilometers to 25 kilometers. These quakes have a recurrence period of about 500 years. Given that about 300 years have passed since the most recent Cascadia Subduction Zone quake, there is approximately a 25% chance that a similar event will occur in the next 50 years.

A Portland Hills earthquake is a surface event with lower likelihood of occurrence (about 2% in the next 50 years) than the subduction event described above, but could have a Richter magnitude of up to 6.5. The Portland Hills fault is about 30-miles long and runs northwest to southeast through Portland. This earthquake is most likely to seriously affect the Vancouver area. Other areas would suffer less damage. Ground shaking from a Portland Hills event would be most severe in the southwest part of the county. The largest impacts would be to the softer soils along the Columbia River and to a lesser extent the Missoula Flood deposits over the lowlands of western Clark County.

The more widely damaging and more likely Cascadia event would cause broad, regional shaking lasting 2 to 4 minutes at a magnitude of as high as 9.0 on the Richter scale as a result of slipping between the two overlapping plates. Slip along this overlapping surface releases large amounts of energy as slow "back-and-forth" movements capable of traveling great distances. Both rapid and slow "back-and-forth" motions occur near the origin of slip at the interface between the two plates. Further from the origin, the rapid motions die out more quickly.

The impact of any earthquake event is largely a function of ground shaking, liquefaction and distance from the source of the quake. Liquefaction results primarily in softer soils. The National Earthquake Hazard Reduction Program (NEHRP) program maps soil characteristics so that areas potentially subject to liquefaction may be identified and appropriate mitigation methods employed. The NEHRP classification system is used for this earthquake analysis. Table 3.2 provides a description of the NEHRP soil classification.

NEHRP Type	Descriptio	Mean Velocity to 30 (m/s)
A	Hard	150
B	Firm to Hard	760-
C	Dense soil, soft	360-
D	Stiff	180-
E	Soft	<18
F	Special study soils soils, sensitive clays, soils, soft clays > 36 m	

Table 3.2: NEHRP Soil Classifications

In Clark County, the areas that will be most affected by ground shaking are located in NEHRP soils D, E and F. These soil types are displayed in Figure 3.2.

In Clark County, areas having NEHRP soils E and F will be more susceptible to motions of ground shaking with peak ground accelerations of 0.3 % of gravity, while areas in soil type D will be less affected between 0.10 and 0.20 % gravity. Soil type E and F would also be susceptible to liquefaction. Ground shaking from a Cascadia event is shown in Figure 3.3. Because of greater distance from the source, base ground accelerations from a Cascadia event would not vary greatly throughout the county. In other words, a Cascadia event will produce similar accelerations throughout the county but structures on some soils will experience greater ground shaking than others. In fact, resonance effects could produce accelerations as high as 0.6% of gravity on certain buildings.

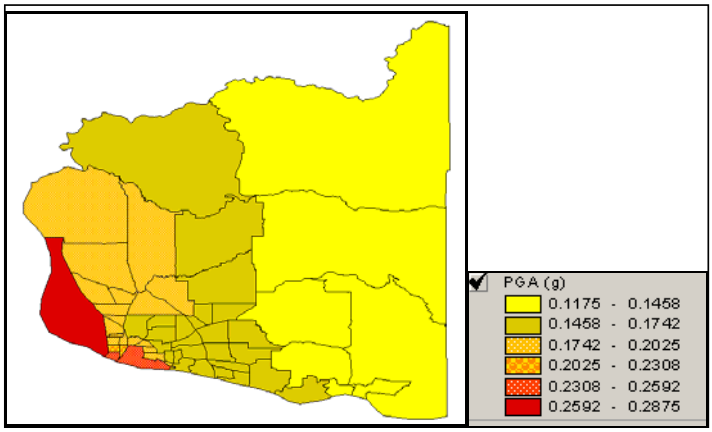

Figure 3.3: Ground Acceleration from Cascadia Event (in percent of gravity)

The degree of ground shaking (or damage) caused by an earthquake is often assigned a numerical value from Roman numeral I to XII on the Modified Mercalli (MM) Scale. This is done so that damage can be assessed and understood. Table 3.3 provides a comparison of peak ground acceleration to the MM intensity scale.[2] Comparison between Figure 3.3 above and Table 3.3 below provide a sense of what a Cascadia quake might feel like on the ground. In the Vancouver area and the plain along the Columbia River (red and orange in Figure 3.3), even reinforced structures are likely to experience significant damage. In the yellow areas of Figure 3.3, damage to structures will likely be slight, though people will feel the shaking and will likely be frightened by it.

A Portland Hills fault event also has the possibility of causing serious damage. Southwest Clark County should expect lateral acceleration 0.3 to 0.4 times the force of gravity for such an event. Duration of a Portland Hills event will be approximately 1 minute or less with wave periods being shorter than for a subduction zone event.

MM Intensity	Peak Ground Accel	Description of Intensity Level
I	0.001	Not felt except by a very few under especially favorable circumstances.
II	0.002	Felt only by a few persons at rest, especially on upper floors of buildings. Delicately suspended objects may swing.
III	0.003	Felt quite noticeably by persons indoors, especially on upper floors of buildings. Many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibration similar to the passing of a truck. Duration estimated.
IV	0.007	Felt indoors by many, outdoors by few during the day. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably.
V	0.015	Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop.
VI	0.03	Felt by all; many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight.
VII	0.07	Damage negligible in building of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken. Noticed by persons driving motor cars.
VIII	0.15	Damage slight in specially designed structures; considerable in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned.
IX	0.32	Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations.
X	0.7	Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations. Rails bent.
XI	-	Few, if any (masonry) structures remain standing. Bridges destroyed. Rails bent greatly.
XII	-	Damage total. Lines of sight and level distorted. Objects thrown into the air.

Table 3.3: Mercalli Scale and Peak Ground Acceleration Comparisons

A warning system for earthquake events has not yet been established; indications of possible subduction zone or Portland Hills activity should not be expected. However, it is known that aftershocks are likely after both subduction and Portland Hills events, so there might be some preparation for these. It is likely that aftershocks may be close in timing to the actual earthquake event.

Secondary hazards

Secondary hazards from an earthquake event are numerous. Liquefaction in NEHRP soil types E and F are a major concern. Other significant secondary hazards are hazardous waste releases, falling objects and fires. Washington State geologists report that a subduction zone event is not likely trigger major landslides.

Vulnerabilities

One of the major concerns for Clark County is that it has experienced a very rapid residential growth rate over the past ten years. Houses built after 1972 are in compliance with the 1970 Uniform Building Code (UBC), which required that all structures be constructed to Zone 2 standards. In 1994, Zone 3 standards of the UBC went into effect in western Washington, requiring all new construction to be capable of withstanding the effects of 0.3 times the force of gravity. This means that more recent housing stock is new and in compliance with Zone 3 standards.

Although residential growth has increased rapidly, commercial development is underrepresented for the population size. Major commercial and industrial businesses are related to the Port of Vancouver. Heavy, regionally based port related industry dominates the Columbia River shoreline. Several different types of hazardous materials are stored on sites, some of which are located in containment areas and some which are not. Clark County provides an important residential alternative and a vital industrial economic driver for the Portland metropolitan area and the region.

Several different types of vulnerabilities exist as a result of this. One of the major concerns is the Port of Vancouver and the Port of Camas and Washougal. Another is infrastructure such as transportation routes, communications systems and necessary facilities.

Man-made and infrastructure vulnerabilities include:

- In terms of estimated replacement costs to man-made improvements, development is concentrated within downtown Vancouver, the Port of Vancouver, Battle Ground, Orchards and Hazel Dell areas.
- The county's industrial base is located within the Port of Vancouver along the shoreline of the Columbia River. The Orchards area also has some industrial uses. Residential development is located away from the Columbia River shoreline along the major arterials. Commercial uses are underrepresented and are distributed within the City of Vancouver, with a second hub in the Camas Washougal area. A brief assessment was done using NEHRP soils data. Table 3.4 presents the number of structures built on different soils type before and after 1972.[3]

Built Date	NEHRP Soils D	NEHRP Soils E and F
Built before 1972	14,146	1,205
Built during & after 1972	29,270	1,656
No date available	3,091	717

Table 3.4: Built Date of Structure

- An assessment was also completed by jurisdiction to determine the number of lots within each city that were in NEHRP soils E and F and were built prior to 1972. Figure 3.4 shows this distribution.

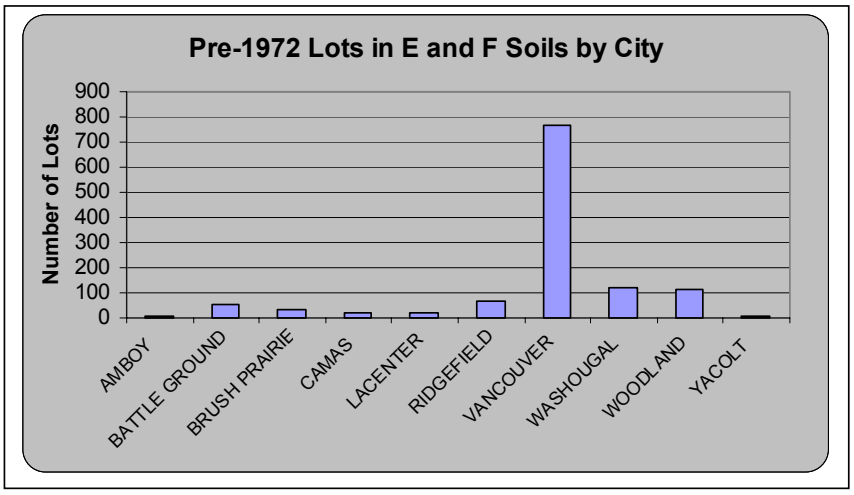

Figure 3.4: Jurisdictional Distribution of Lots on NEHRP E & F Soils

- Light wood frame construction is dominant within the county in terms of exposed dollar value. Extent of anchoring to foundations is not known precisely but can be related to building code requirements for anchoring, which date to 1972. Masonry construction is scattered throughout the county. Un-reinforced masonry structures are most common, though not predominant, in downtown Vancouver, downtown Camas, and the Walnut Grove area. The industrial areas of the county predominately consist of steel and reinforced concrete.
- Emergency Response facilities are decentralized and located through out the county.
- County government buildings, including the Clark Regional Emergency Services Agency, which contains the Emergency Operation Center where all response activities are coordinated, are new and located within a consolidated campus in City of Vancouver. Because many government functions are located in proximity of one another, serious damage in that area could be devastating. City offices are older and located with their respective jurisdictions.

- Utilities infrastructure such as water, sewer, and/or electrical power may be interrupted.
- Group quarters (apartment complexes, etc.) are largely located with the downtown area of the City of Vancouver.
- Many schools have been recently constructed to meet the demands of a rapidly growing population. These are consequently relatively earthquake resistant, code-compliant structures. However, there are a number of older, formerly rural schools now serving suburban areas that are vulnerable and have not been retrofitted.
- The county vehicular intra-county transportation system is generally characterized by the lack of redundancy and dependency on bridges. The County north/south vehicular corridors include Interstate 5 (I-5) and Interstate 205 (I-205). There is limited north/south redundancy via a series of local roads. east/west traffic is restricted to Route 14 along the Washington side of the Columbia River and Route 30 on the Oregon side. Limited East/West redundancies are possible along East Mill Plain Boulevard, NE Fourth Plain, NE 76th Street, and SR 500. Most corridors include numerous bridges.
- Separated by the Columbia River, cross-river traffic is dependent on I-5 and I-205. The I-5 Columbia Bridge has had some limited retrofit in recent years; however the major structures date to 1917 and 1958.
- Oregon elements of a regional transportation network are more dependent on bridges than Clark County.
- Port structures are built on some of the least consolidated soils in the county.
- Many structures in Yacolt were built prior to the 1972 earthquake codes and have not been retrofitted. The fire station in Yacolt has not been earthquake retrofitted. This building also acts as the Northwest Area Emergency Command Center, thus its functionality is essential to this area.
- The Portland Metropolitan area and the local Clark County ports drive the County economy.

Natural systems vulnerabilities include the major concentrations of hazardous materials concentrated within the port industrial lands along the Columbia shoreline upriver of the Lake Vancouver wetland area and the Ridgefield Wildlife refuge.

Capabilities

Revised building codes: Washington State adopted a revised building code that will go into affect in 2004. The Washington State Building Council is determining the specific requirements but more than likely will require the implementation of the International Building Code. This offers an opportunity for new risk reduction in construction.

NEHRP Soils Map: The Washington Department of Natural Resources is in the process of completing a revised NEHRP Soils map for Clark County. The map when complete should be adopted by reference, supporting the implementation of the International Building Code. Drafts of these maps were used for the above-mentioned HAZUS runs.

Home retrofitting: Clark County has incorporated the Seattle Home Retrofitting program and has adopted the prescribed engineering documents and expedited permit procedure.

Outreach: Clark County is a FEMA "Project Impact" Community and through this initiative has met with schools in support of nonstructural mitigation efforts.

Earthquake damage reduction information. Information is readily available through government agencies and via their web sites. Examples include:

- FEMA "880" series worksheets for property owners.
- Earthquake Hazard Mitigation Handbook for Public Facilities.

Small Business Loan Program: The Small Business Administration (SBA) has approved a Pre-Disaster Mitigation Loan Program that makes low-interest, fixed-rate loans to eligible small businesses for the purpose of implementing mitigation measures to protect business property from damage that may be caused by future disasters. The program is a pilot program, which supports the Federal Emergency Management Agency (FEMA) Pre-Disaster Mitigation Program. Mitigation is defined as measures for the purpose of protecting real and personal property against disaster-related damage. Examples of mitigation measures include retaining walls, sea walls, grading and contouring land, elevating flood-prone structures, relocating utilities, and retrofitting structures against high winds, earthquakes, floods, wildfires, or other disasters.

Support following a presidential declaration. There is considerable support for risk reduction measures following a federal declaration. Often these programs and their implications are not taken advantage of before permanent repairs are made.

- Some of the more significant ones include:
- The Hazard Mitigation Grant Program (HMGP) offers assistance for a wide range of mitigation projects following a presidential declaration. Eligibility is restricted to projects that have gone through a comprehensive hazard mitigation planning process.
- Minimal Repair Program often funds risk reduction such as the anchoring of mobile homes.
- The Small Business Administration will fund eligible mitigation measure to qualified owners of damaged homes.
- Outreach is available through Disaster Reconstruction Assistance Centers (DRACs), Recovery Information Centers or Hazard Mitigation Teams
- Benefit/Cost Mitigation support is available from FEMA on infrastructure repair. To break the damage-rebuild-damage cycle FEMA Region 10 is encouraging communities to:
    - Institute mitigation betterments taking advantage of multi-hazard, multi-objective approaches whenever possible
    - Strengthen existing infrastructure and facilities to more effectively withstand the next disaster
    - Ensure that communities address natural hazards through comprehensive planning

Following a Federal Declaration FEMA can support cost effective mitigation on infrastructure and have published a manual on the subject.

Washington State Growth Management Act. Clark County has updated their Critical Areas Ordinance.

Flood Insurance Study. The county is in the process of revising its Flood Insurance Study. This process offers opportunities to not revise the data but to heighten awareness of county flood risks.

Scenario

A Cascadia Region Subduction Zone event having an 8.5 magnitude, though it could actually be somewhat higher, is realistic and probable. Potential levels of damage were calculated by HAZUS (a modeling program created by FEMA which produces loss estimates for earthquake events) using default damage functions and inventories. The HAZUS results provide a baseline of potential damage using models developed for non-subduction zone earthquakes.

The HAZUS "run" factors in a total 2000 census population of 345,238 people. The densest population is the metropolitan areas along the I-5 and I-205 corridors in Vancouver and also along SR-14 (which passes through Camas and Washougal). The scenario recognizes a growth rate of approximately 20% with dramatic implications for trade through the Port of Vancouver.

An 8.5 Cascadia Region Earthquake will generally result in light to moderate damage within the larger Clark County. Heavy damage will occur in areas having poor site conditions, older construction, or construction especially vulnerable to the long duration, long period ground motions that can cause damage in areas over 100 kilometers from the earthquake's origin. Access to and from Clark County will be the greatest problem with the functional loss of key bridges.

Buildings

Subduction zone earthquakes concentrate a large amount of released energy in long period movements, i.e. slow back and forth movement, of the ground. The size of the earthquake results in the ability of these long period motions to travel great distances from their origin within the subduction zone. Buildings that resonate with the period of ground shaking generated by the earthquake will sustain greater damage. Depending on soil type and depth, ground-shaking periods of 0.1 to 1.0 seconds may be generated by an earthquake in Clark County. A period of 1.0 second would resonate most strongly with buildings of about 10 stories. Older 10-story concrete frame buildings are particularly sensitive to these motions. While reinforced masonry buildings are relatively stiff buildings, they do have some sensitivity to long period motions related to softer connecting elements, such as wood diaphragms.[4] Reinforced masonry structures in and around the City of Vancouver would experience at least moderate structural damage. Un-reinforced masonry buildings would likely experience major structural damage or failure. Table 3.5 shows damage state probabilities for different types of structure construction.[5]

Type of Structure	Damage State Probability (%) None	Moderate	Extensive	Complete
Concrete	12.33	29.69	28.78	16.13
Mobile Home	8.07	28.96	32.67	18.31
Pre-cast Concrete	11.71	25.45	32	21.91
Reinforced Masonry Bearing Walls	20.16	27.13	29.18	12.58
Steel	10.15	26.62	31.07	23.31
Un-reinforced Masonry Bearing Walls	28.53	25.51	15.36	9.18
Wood	48.76	19.42	5.2	1.82

Table 3.5: Building by Building Type for Low Design Level (based on 1990 data)

Damage states vary for each type of structure. Moderate to very heavy damage will occur in older residential neighborhoods, business districts, communities with concentrations of non-seismically designed buildings, and areas built on soft soils located mainly in the Vancouver area. Particularly vulnerable are homes built before 1950, turn of the century un-reinforced masonry buildings, pre-1972 homes that were built prior to the 1970 UBC that required anchoring to the foundations, pre-1980 tilt-up buildings, and buildings with large windows or parking doors that weaken the first floor. Least vulnerable would be structures built since 1994 when the earthquake Zone 3 standards of the UBC were applied.

The scenario event was most damaging to 3 story structures (0.3 second spectral accelerations) resting on softer soils. Buildings tend to move in response to shaking that is close to their natural frequency. Thus, a short stiff building will be more easily moved by "short" period or rapid back and forth movements.

Three-story port structures on softer soils in the Vancouver area could expect accelerations ranging from 0.54 to 0.67 percent of gravity. Wave energy would attenuate rapidly, with shorter structures with the Port of Camas receiving slower thought still damaging accelerations ranging from 0.34 to 0.40 percent of gravity.

Taller structures would receive reduced accelerations (1 second spectral accelerations). 10 story structures supported by the softer soils located with Vancouver port areas could expect accelerations of 0.44 to 0.50 percent of gravity. Port of Camas soils would receive accelerations of 0.20 to 0.26 percent of gravity. Nonstructural damage would be especially severe in taller buildings, which will sustain large displacements. The movement of taller buildings may damage adjacent buildings by pounding against them, causing significant damage to buildings that otherwise would have been undamaged.

Single story structures may expect accelerations ranging from 0.26 to 0.29 (Port of Vancouver area) and 0.11 to 0.14 (Port of Camas area) percents of gravity respectively.

Short structures built on lands along the along the I-5 and 205 corridor would receive acceleration from 0.34 to 0.47 percent of gravity and those surrounding the Camas/Washougal area would be subject of 0.34 to 0.40 percent gravity.

Many older county homes would have structural damage, particularly with principal structures drifting off of their perimeter foundations. Damage to newer homes, not located on softer soils, would be limited to chimneys and other nonstructural elements. Older schools may also suffer significant seismic damage. The Evergreen School District is of particular concern because none of the school structures have been upgraded for earthquakes. The Lewis River dams are not

likely to fail. Table 3.6 displays damage state by building occupancy type.[6] Residential occupancy is the largest in Clark County but sustains the least amount of complete damage. A total of 17.69 % of industrial occupied buildings in Clark County sustain complete damage with only 13.55% having no damage at all.

	Square Footage	Damage State Probability (%)				
	(Thousand. sq.ft)	None	Slight	Moderate	Extensive	Complete
Agriculture	374	27.58	11.84	14.53	13.60	8.69
Commercial	16,636	15.47	14.73	29.60	25.29	14.98
Education	1,063	19.95	10.16	16.16	15.55	9.09
Government	489	14.25	12.64	28.42	27.84	16.80
Industrial	11,669	13.55	12.82	28.55	27.27	17.69
Religion	1,576	23.75	12.73	20.29	19.56	10.93
Residential	126,599	59.78	22.36	10.58	4.96	2.29
Clark County Average	158,407	24.90	13.90	21.16	19.15	11.50

Table 3.6: Building Damage by General Occupancy (based on 1990 data)

Port

The Port of Vancouver area would be subject to the greatest ground shaking and liquefaction impacting 3-story structures most severely. The area would represent that with the greatest percentage and number of 'at least moderately damaged' industrial structures in the county. Business resumption is a complex issue. However, based on recent research, some business may not survive, thereby impacting the regional economy.

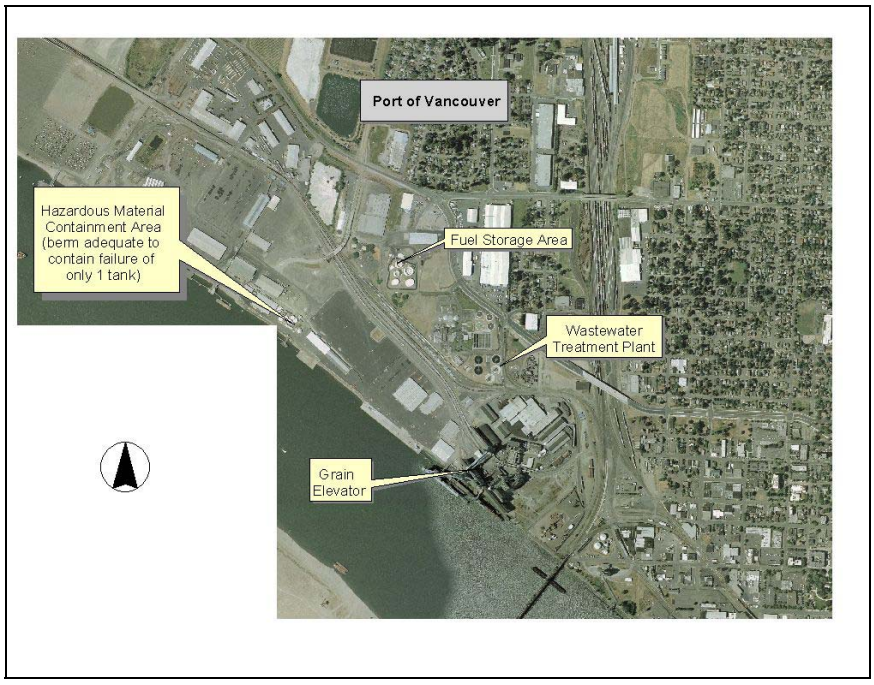

Figure 3.5: The Port of Vancouver

Structures located with the Port of Vancouver facilities and containing hazardous materials are particularly susceptible to liquefaction and flow into the Columbia impacting down river wetlands (See Figure 3.5). When liquefaction occurs, the ground loses the capability to support structures, resulting in subsidence and/or tipping of buildings and bridge supports. Lateral spreading pull apart some types of buildings and rupture pipelines.

Several tall grain elevators could potentially fail. These are located at the Port of Vancouver, where 16 % of the grain from the Columbia River Drainage Basin is exported. The loss of these would have significant economic impacts in this region.

Transportation Systems

Commuter traffic to and from Oregon will be severely interrupted. Regional transportation would be interrupted on the day of the event principally by bridge failures. I- 5 and I-205 from the Oregon/Washington boarder north would be functional on day 2. By day three Clark County North/South and East/West corridors will be functioning. However, regional Oregon/Washington North/South corridors would not be functioning due to Oregon bridge failures. Approximately 60,000 people commute over the bridge daily. Table 3.7 shows bridge damage state probabilities.[7] Figure 3.6 displays Clark County bridge functionality on the day of the earthquake event.

Number of Bridges	Damage State Probability (%)				
	None	Slight	Moderate	Extensive	Complete
268	77%	13%	4%	4%	2%

Table 3.7: Bridge Damage (based on 1990 HAZUS data)

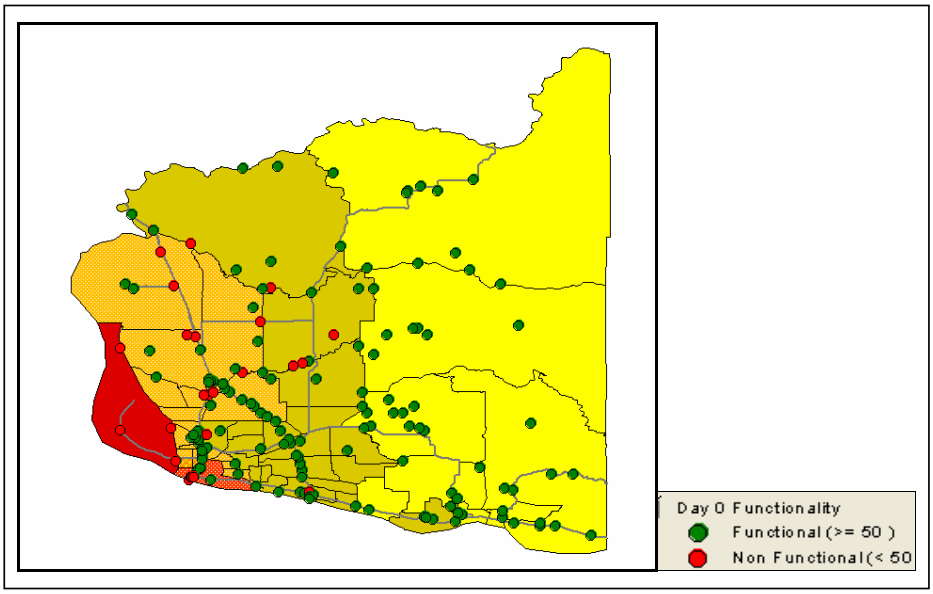

Figure 3. 6: Bridge Functionality on Day of Earthquake

Railway lines may be disrupted. Many are located in the port area on unconsolidated soils. The railroad bridge crossing may suffer damage. All county airports should be functional on day 1 of the event.

As a result of the damage to the bridges crossing over the Columbia River, the Portland, Oregon area may be inaccessible. In a major hazard event, it is likely that emergency services as well as critical facilities in Portland would be needed or would be working with Clark County for response. The lack of bridge functionality would cause significant problems of access to emergency response such as hospitals, fire and police for Clark County and Portland. Clark County would be isolated from the services usually available from the Portland area.

Critical Facilities/Medical Services

The County government facilities, including Clark Regional Emergency Services Agency would survive with minimum damage but would be isolated due to debris from failing neighboring structures. Most injury would come from being hit by non-structural elements. Emergency response facilities may suffer isolation. Hospitals in the Portland area may not be accessible as a result of bridge or route failures. There is one major hospital, called Southwest Washington Medical Center, in the area with another one being planned near the Salmon Creek area. This hospital has 360 beds. During this scenario only 29 hospital beds would be available on the day of the earthquake. Ninety days after the earthquake event, a total of 219 hospital beds would be available.

Loss estimation

Potential losses from the earthquake described above would be significant for Clark County, but could be at least as high as $187,615,200 (including residential losses and bridge losses, but excluding the incalculable loss of human life and economic losses). The following is a brief summary.

Loss Summary	
Residential losses:	$130,615,200
Residential losses possible given growth potential:	$192,816,720
Loss of life:	15,805 people
Bridges:	$57,000,000
Economic loss:	Difficult to calculate; includes immediate loss of commercial and industrial properties (1,964 exposed lots), related job loss, loss of revenue from workers unable to commute to work (down bridges and destroyed roads), loss of revenue from workers killed, long-term economic effects of changed market, etc.

Table 3.8: Estimated Losses in Clark County from Earthquake in Clark County

This loss estimation considers residential lots in two different risk categories: those built on soils that have a high likelihood of liquefaction and those with a moderate risk of liquefaction. There are a total of 1,476 residential structures built within UGAs on soils with a high risk of liquefaction. A conservative loss estimate for these structures, based on HAZUS methodology, is

25%. In other words, in an earthquake, these homes can be expected to lose 25% of their value. The number of lots was multiplied by the average cost of homes in Clark County ($156,600[8]), and the resulting number multiplied by 0.25 to arrive at a loss estimate for high risk homes of $57,785,400. There are 4,603 homes built on soils with a moderate risk of liquefaction. An earthquake on this type of soil is estimated to destroy 10% of a home's value. The loss estimate for these homes is $72,829,800. The sum of loss estimates for high liquefaction risk and moderate liquefaction risk represents the overall residential loss number above.

These numbers may be an underestimate, as they do not include the 2760 built parcels in unincorporated areas that are not defined specifically as 'residential.' The majority of these parcels, however, are probably in residential use. If these parcels are considered, the residential loss figure jumps to $200,920,770.

Loss estimates considering growth potential assume a 'built out' scenario in which every developable parcel has a residential structure on it. Currently, there are 7944 developable properties in Clark County that will be prone to either high or moderate risk of liquefaction. Because this development, when it occurs, will be built to the highest earthquake resistant code, it is estimated to only result in a loss of 5% of the value of the property. Buildable lots could, in this scenario, total $62,201,520. The loss estimation number above includes both built and buildable parcels in jurisdictions and in rural areas.

Loss of life is calculated by multiplying the number of homes existing in areas subject to high and moderate risks (6079 lots) of liquefaction by the average household size (2.6[9]) in Clark County. This number does not account for people in the risk area who do not live there and instead work there or commute through there. Actual loss of life could vary greatly depending on the time of day that the earthquake occurs and the magnitude and epicenter location of the earthquake. It is impossible to place a dollar value on human life.

HAZUS estimates a total value of bridges in Clark County at $950,000,000[10]. When the Cascadia Subduction Zone event was run through the HAZUS model, it showed 4% of bridges would suffer extensive damage, and 2% would be totally destroyed. The $57,000,000 loss estimate includes the value of the 6% of bridges that would be either extensively or totally damaged.

In addition to the loss calculated above, there could be extensive damage to roadways, gas, water, and electric lines, and personal property of other types (cars, home interiors, etc.).

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[1] Clark County Communications Agency. ***Clark County Hazards Inventory Vulnerability Assessment.*** 11/06/2000.

[2] Cascadia Region Earthquake Workgroup, Professor Anthony Qamar, University of Washington

[3] Note: The year 1972 was used to determine the number of structures built under Zone 2 or better standards of the UBC. Although the Zone 2 standards were required in 1970, full compliance with building construction did not occur until 1972.

[4] HAZUS Scenario. ***Clark County 1***.

[5] HAZUS Scenario. ***Clark County 1***.

[6] HAZUS Scenario. ***Clark County 1***.

[7] HAZUS Scenario. ***Clark County 1***.

[8] U.S. Census Bureau, 2000

[9] U.S. Census Bureau, 2000

[10] In 1990 dollars

Chapter 3b
Flooding

Definitions

Base Flood Elevation

The base flood elevation is the elevation of a 100-year flood event, or a flood, which has a 1% chance of occurring in any given year.

Floodplain

Floodplains are generally defined as the lands adjacent to major rivers or streams that have a 1% chance of being flooded in any given year. FEMA has mapped these areas throughout the country, and most communities in the United States regulate development within them. In Clark County, two floodplains were mapped, those that have a 1% chance of flooding in any one-year and those having a 0.5% chance.

Floodway

Floodways are areas within a floodplain that are reserved for the purpose of conveying flood discharge without increasing the base flood elevation more that one foot. Generally speaking, no development is allowed in floodways, as any structures there would block the flow of floodwaters.

Floodway Fringe

Floodway fringe areas are those lands that are in the floodplain but outside of the floodway. Some development is generally allowed in these areas with a variety of restrictions.

FEMA contracted the Army Corps of engineers to map the floodplains, floodways, and floodway fringes of Clark County in 1981. Figure 3.7 depicts the relationship among the three designations.

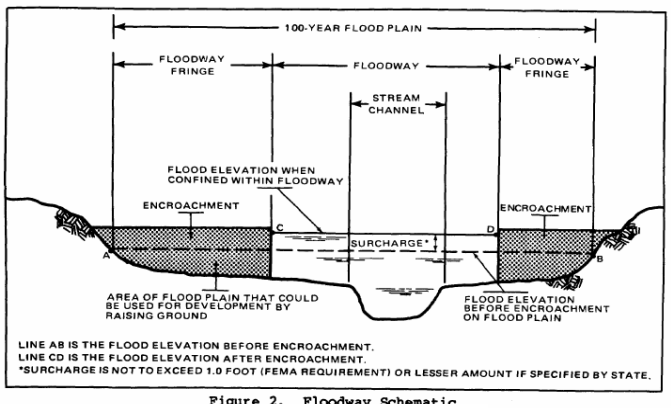

Figure 3.7: Floodway Schematic

Zero-Rise Floodway

A 'zero-rise' floodway is an area reserved to carry the discharge of a flood without raising the base flood elevation. Some communities have chosen to implement zero-rise floodways because they provide greater flood protection than the floodway described above, which allows a one foot rise in the base flood elevation.

Flood Insurance Rate Map (FIRM)

FIRMs are the official maps on which the Flood Insurance Administration has delineated areas of flood risk and risk premium zones.

Low Impact Development

Low Impact Development[1] is a comprehensive land planning and engineering design approach with a goal of maintaining and enhancing the pre-development hydrologic regime of urban and developing watersheds. This design approach incorporates strategic planning with micro-management techniques to achieve environmental protection while allowing for development or infrastructure rehabilitation to occur.

Comment: I took this out only because I already included it in the background section for the document as a whole.

Flood Hazards in Clark County

Clark County has the temperate climate typical of western Washington. Summers are dry with mild temperatures, and winters are rainy with occasional snow. Average annual precipitation varies from 39 inches at Vancouver to 75 inches at Yacolt in north-central Clark County. The soils of the northern and eastern areas are well drained, while those of the western and southern areas are poorly to moderately drained. [2]

Floods occur in Clark County every few years, and major events occur with some frequency. There have been 6 major events since 1933. In Clark County, flooding is most likely to occur due to a severe winter storm that brings snow to the higher elevations, followed by warmer weather and rain. The sudden influx of new rain and melting snow can overwhelm both natural and man-made water drainage systems.

An example of the type of flooding typical throughout the county is the event that occurred on November 29, 1995. It resulted from an extended series of rainstorms generated over the Pacific Ocean that moved north and east across California, Oregon and Washington. Flooding in Clark County occurred when relatively intense rain fell on saturated ground surfaces and already swollen creeks and rivers. Runoff from snowmelt also contributed to high flows in the North and East Forks of the Lewis River, and the Little Washougal and Washougal Rivers. The floods were somewhat severe, with peak flows in county streams ranged from approximately a two-year flood in Burnt Bridge Creek to a 25-year flood in Salmon Creek.[3]

Comment: Still don't think we need this

The storm of November 1995 was not considered to be a major flood-producing storm for the Columbia River. However, relatively high stream base flows and tides did combine to produce river levels exceeding flood stage within the portion of the Columbia River flowing through Clark County. Ten houseboats were evacuated at Ridgefield due to sewer problems caused by high river elevations. Higher Columbia River elevations also produced backwater in the lower reaches of Salmon Creek, contributing to the evacuating of approximately 15 additional houses. Some condominiums and restaurants also experienced flooding along the Columbia River.

Floods in Clark County can generally be classified into four different types:

- Flooding resulting from overflow of the Columbia River, distinct from general riverine flooding both because of the magnitude of flooding possible and because of the slow rising nature of these floods.
- Riverine flooding, which occurs primarily in designated floodplains in the interior of the county and side drains to the Columbia River.
- Shallow flooding or ponding in "sink areas," which may occur well outside of mapped floodplains and generally results either from areas of very high water table (which can over saturate during storm events), or from areas of poor soil percolation (where rain water simply does not drain effectively during storm events).
- Isolated flooding may result from clogged or overflowing storm drainage systems and culverts.

The remainder of this section will describe each of these types of floods in greater detail. Figure 3.8 depicts 100-year floodplains in Clark County, the areas most likely to be affected by flooding.

Columbia River Flooding

Historically, most of the development in the county has been along the Columbia River corridor, which forms the southern and western boundaries of the county. The river is the major inland waterway in the northwestern United States. It drains an area of approximately 241,000 square miles of southwestern Canada and Northwestern United States upstream of Vancouver Washington.

Although many large Columbia River floods have occurred in Clark County, existing flood control storage structures (reservoirs and dams) reduce flood elevations and provide increased warning time for those who live in the flood's path.

The entire Columbia River Basin includes more that 50 storage projects resulting in significant reductions in flood elevations. Also significant in controlling risk within Clark County are drainage district levees, which provide varying flood protection capacity. These include:

- In the vicinity of Vancouver, some protection from the Columbia River flooding is provided by levees along Lower River Road and at Fruit Valley. However, certain known deficiencies in their design and maintenance limit the degree of protection to below the 100-year flood level for the Lower River Road area and below the 500-year flood level for Fruit Valley area.
- Southwest of Ridgefield at Lake River Delta and Bachelor Island are 2 projects that include levees, pumping stations, tideboxes, and interior drainage canals. Again, however, known deficiencies have limited the degree of protection they provide.
- The Washougal Area Drainage District, constructed by the Army Corps of Engineers in 1967 and 1966 extends 5.5 miles along the Columbia River from Lawton Creek west to Camas and includes levee embankments, revetments, tide box, and freshwater inlets and a pumping plan with interior drainage canals.

These flood control structures have reduced the frequency and severity of flooding along the Columbia River. The floodplain is well defined and residents have experienced several weeks' notice of approaching floodwaters. However, continued maintenance is crucial if these structures

are to remain successful. Should they be ignored, the severity of the impact of a future flood would be greater than if the structures had not been built to begin with.

Riverine Flooding

Another type of flooding occurs along the smaller rivers in the interior of the County. Figure 3.9 shows the County's watershed boundaries, the area's natural drainage system. Clark County watercourses[4] generally flow westerly and southerly from sources in the steep timberland watershed, pass through lower reaches of gently sloping agricultural and developing residential lands, and flow into the Columbia River. Flooding along these rivers and streams is distinct from Columbia flooding in several ways. First, the rivers are smaller and have less capacity for carrying water, so that the flooding, while no less severe for those experiencing it, affects a smaller number of homes. Second, there are fewer dams and reservoirs along interior rivers, making flooding somewhat less predictable.

In general, minor flooding occurs along the banks of the upper reaches of most streams; however, when two streams merge, floodwaters can back up into the smaller stream, creating a backwater that can mean more severe and more frequent flooding for residents near the confluence. In the 1995 floods, this scenario was the principle cause of flooding along the Lewis River. Flood-waters from the Columbia backed up into the Lewis, flooding the area. Salmon Creek, East Fork of the Lewis River, Washougal River, Burnt Bridge Creek, and Mill Creek all follow this historical pattern of flooding.

Washougal River

The largest flood on the Washougal River since a USGS stream gauge was installed in 1944 was on December of 1977, 6 miles upstream of the City of Washougal. There was little damage however, largely because at that time there was limited development along that stretch of the river. The amount of development is increasing, however, making future flood damages more likely.

Lewis River

The Lewis River is regulated by three storage projects: Swift Reservoir, Yale Reservoir and Lake Merwin Reservoir, all of which are operated by Pacific Power and Light (PP&L). The largest flood on the Lewis River occurred in 1933 before these were built. Under the present Federal Energy Regulatory Commission (FERC) license, PP& L is not required to reserve storage for flood protection; however, on August 18, 1983, FEMA, and PP&L agreed to make approximately 70,000 acre-feet available for flood control storage on the Lewis River System at Merwin Dam, thus reducing the 100-year discharge at Woodland from 128,000 cfs to 102 cfs, further reducing risk of flooding to residents of Woodland.

PP & L have prepared emergency operation procedures for three danger conditions: "non-failure emergency" conditions (high flows), "potentially hazardous conditions," and "failure is imminent or has occurred" conditions. They have not established the risk of each condition occurring, but state that the dams are in very good conditions as certified by independent consultants. The likelihood of catastrophic failure of the three dams along the Lewis River was assessed and their failure was determined not to represent an additional risk to development within the inundation zone.[5]

Comment: It would be helpful if you could add in a quick assessment of the risk on each river, even just broadly here. High? Low?

Shallow flooding

Much of the south and western urban growth areas have poorly to moderately drained soils, a condition which leads to the ponding of water in lower elevations. During heavier rainstorms, water neither seeps into the soil or drains off, and can potentially flood homes. The condition

was evidenced during the 1996 storms captured in aerial infrared imagery, as shown in Figure 3.10.

This area, west of Battleground, shows an example of shallow flooding. SR 502 runs across the picture on the lower half of the image.

Figure 3.10: Shallow Flooding Example

Flooding related to drainage structures

An analysis after the 1995 floods showed drainage structures to be a major contributor to ponding and flooding during the event.[6] Many existing culverts and drainages were judged to have been inadequate to efficiently move the rainwater that fell onto urban infrastructures (road, roofs, sidewalks, etc.) into rivers. This situation lead to urban flooding distant from mapped floodplains and floodways. According to this post-1995 flood engineering report, a lack of well functioning storm sewer structures and increasing runoff from urbanization has led to an increasing number of drainage problems during storms. Limited resources meant that maintenance crews were unable to respond to flooding problems in many areas in a timely manner. The engineering team commented that maintenance crews can manage some drainage problems, such as plugged inlets, but capacity problems (under-designed subdivision storm systems) require significantly more complex solutions. Operations crews were unable to prevent flooding in these situations.

In an essentially rural county, drainage problems tend to be minimal and are manageable within the limits of a rural public services budget. However, Clark County is now a rapidly urbanizing county and it is evident that present County funding is not sufficient to provide a reasonable level of drainage and flood control services to county citizens. Significant capital funding needs to be developed to provide drainage and flood control infrastructure extensions and improvements within the County, especially given the rapid growth it is currently experiencing.

All of the assessments made in this report documented the successes of "softer structures" such as contouring, engineered swales and introduced vegetation. New research suggests that opportunities for improved stormwater management might come from low intensity development (LID, defined above) and not from new and improved traditional structures.

It is also important to note that, in some cases, blocked drainage structures can provide important retention functions, and actually slow the process of the water moving downstream in much the

same way that a natural system, such as a wetland, might. Basin-wide analysis is necessary to determine which drainages should be improved to speed the flow of storm water, and which should be maintained. This sort of analysis also coincides with the principles of LID.

Secondary Hazards

Secondary hazards include landslides, which can occur as a result of flooding when the ground is saturated. Landslide hazards will be discussed in the landslide sections. Additionally, chemicals or other toxic substances stored without appropriate protection in the floodplain may be released into floodwaters. Septic systems may cause additional water contamination.

Vulnerabilities

Vulnerabilities can be thought of as any man-made or natural system or structure that is impacted by a hazard. Each will be discussed as they relate to Columbia River flooding, riverine flooding, shallow flooding and flooding that results directly from urban runoff.

In 1995, Clark County experienced severe flooding. A total of 30 people were evacuated from their property, 35 homes were flooded and 20 roadways were closed. All rivers in the County including the Columbia River were affected. The event additionally resulted in shallow flooding in areas distant from rivers and streams. Clark Regional Emergency Services estimated known property damage from flooding to be $704,564 in addition to the combined $95,000 in expenditures for Clark County Emergency Services and Operation Division. Over $1 million in damages to urban water related structures were incurred. This flooding event may not offer the worst-case scenario, but it does offer an event from which to assess the county's vulnerability and the cost associated with flooding.

Columbia River Vulnerabilities

Few residential structures are directly exposed to flooding from the Columbia River, in part because much of the area along the river is not residentially zoned. Those residential structures that are impacted by high water when the Columbia River floods are generally flooded as a result of the restricted flows of rivers and streams draining into the Columbia.

The commercial development vulnerable to the flooding of the Columbia River includes primarily hotels and restaurants. During the 1995 flood, most commercial uses along the river were interrupted. Newer commercial development is appropriately elevated above the 100-year flood level. Since these floodplain fringe areas did not experience high floodwater velocities or large debris in the flows, the elevated structures faired quite well in the floods. Older structures, however, are more vulnerable.

Industrial development along the floodplain is largely protected through a combination of building elevation and fill (as is the case of the Port of Vancouver), or by levees. Perimeter levees of a particular drainage district may be capable of withstanding large floods, yet major rainstorms could cause extensive interior ponding in lower areas if runoff exceeds the capacity of the dewatering-drainage pumps. Without regular maintenance, the functionality of any levee will decline.

Ports facilities are vulnerable, although protected by levee systems and fill and ring dikes around vulnerable structures. Nonetheless an extremely severe flood on the Columbia River could breach dikes and lead to flooding in port areas. The port is a major employer and a regional economic driver. Any loss of function at the port would impact the entire region.

The Vancouver water treatment facility is located in the floodplain and protected by a series of ring dikes. These were not severely damaged during the 1995 floods and operation was not interrupted.

The Vancouver Wildlife sanctuary, which lies downriver from the Port of Vancouver and the Vancouver sewage treatment facilities, is potentially vulnerable to floods and the pollution they may carry. During the 1995 event, floodwaters flowed over port lands and onto these critical areas. However, because the port chemical storage tanks and the Vancouver sewage treatment facilities remained intact, the sanctuary was not severely impacted.

Riverine Flooding Vulnerabilities

The major issue related to riverine flooding in Clark County is the large number of new homes that could be constructed in floodplains. Any new development built in a floodplain increases the number of residences and other structures exposed to flooding, increasing risk to life and property along with the damage figures from any flood event. Large numbers of additional homes in the floodplain mean that even floods that are now considered minor could cause large amount of damage in the future.

While new construction in Clark County floodplains exceeds the development standards required by the National Flood Insurance Program, risk is not entirely eliminated, especially given the fact that so much new development is occurring in the floodplain. Additionally, development, even when compliant with NFIP standards, is served by infrastructure that is vulnerable to flooding. Individual homes may be resistant to flooding, but the roads and drainage systems that serve them could flood, leading to isolation and property damage. Almost 80% of all of the structures insured through the National Flood Insurance Program (NFIP) cover structures constructed since 1980, and 60 % have been built since 1990. Since flood insurance is required on new development if it falls within the floodplain, this figure evidences the increasing number of structures in flood prone areas. Figure 3.11 below shows the change in flood insurance policies on new development in the county. Most of these policies insure structures in the unincorporated areas of the county.

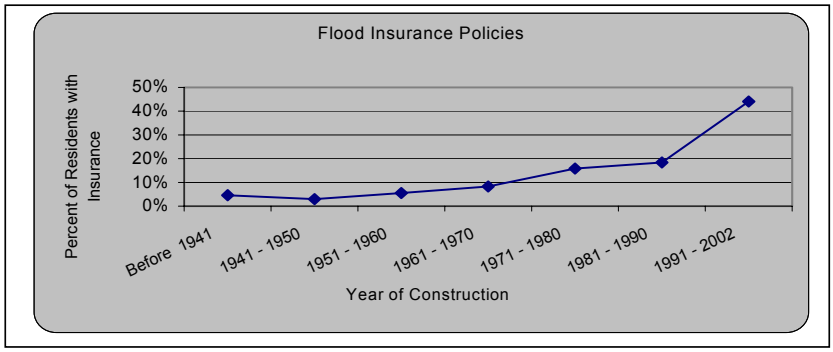

Figure 3.11: Floodplain Development Evidenced by Flood Insurance Policies

Floodplain development has been extensive during the past decade; however, there remains an important opportunity to guide future growth. Table3.9 lists all lots[7] in the county that are located in a floodplain. A little over half of all floodplain lots are developed with residential land uses. The large number of developable yet undeveloped lots suggests that the number of flood-prone homes could easily increase by a third along most watercourses (assuming that a single house is placed on a single lot). Table 3.9 below compares developed lots with undeveloped lots. It is

important to note that many of these potentially developable lots are large enough to be subdivided, making these estimations quite conservative.

City	Floodplain		CURRENTLY DEVELOPED			TOTAL DEVELOPED	DEVELOPABLE LOTS			TOTAL DEVELOPABLE
			residential	commercial	industrial		residential	commercial	industrial	
Battle Ground	Salmon Creek	lots	94	26	0	120	59	10	0	69
		acres	19.0	13.3	0	32.2	162.0	1.9	0	163.9
Camas	Camas	lots	18	1	296	315	41	7	25	73
		acres	1.3	0.0	429.3	430.6	6.2	0.0	12.9	19.2
	Lacamas Creek	lots	174	0	8	182	160	2	62	224
		acres	40.2	0	28.1	68.3	65.9	0.0	105.2	171.1
	Washougal River	lots	228	8	9	245	123	52	22	197
		acres	14.9	3.8	21.4	40	21.9	11.7	2.4	36
Ridgefield	Bachelor Island	lots	0	0	0	0	1	0	0	1
		acres	0	0	0	0	0.8	0	0	0.8
	Flume Creek	lots	31	3	0	34	11	11	0	22
		acres	1.1	7.8	0	8.9	29.2	12.6	0	41.8
	Gee Creek	lots	66	2	0	68	114	1	0	115
		acres	9.3	4.6	0	14	60.0	0.0	0	60
Vancouver	Burnt Bridge Creek	lots	251	7	27	285	280	22	95	397
		acres	65.0	13.1	93.3	171.4	179.5	1.8	151.1	332.4
	Lacamas Creek	lots	0	0	0	0	4	0	0	4
		acres	0	0	0	0	5.8	0	0	5.8
	Lakeshore	lots	4	0	0	4	25	0	0	25
		acres	0.0	0	0	0	0.1	0	0	0.1
	Salmon Creek	lots	234	8	4	246	356	15	5	376
		acres	46.4	13.5	1.4	61.3	481.6	13.8	1.1	496.5
	Vancouver Lake	lots	29	0	89	118	22	0	159	181
		acres	12.3	0	330.4	342.6	10.0	0	1230.4	1240.4
	Vancouver South Slope	lots	191	17	111	319	191	49	162	402
		acres	28.1	6.2	241.3	275.6	58.2	57.0	185.8	301
Washougal	Gibbons Creek	lots	0	0	5	5	1	0	19	20
		acres	0	0	9.7	9.7	0.006	0	24.4	24.4
	Washougal River	lots	442	5	6	453	257	42	5	304
		acres	63.1	0.5	4.8	68.5	74.5	17.1	6.3	98
Yacolt	East Fork Lewis River	lots	1	0	0	1	1	0	0	1
		acres	0.1	0	0	0.1	0.06	0	0	0.1
TOTALS	**Total Floodplain Development**	lots	**1763**	**77**	**555**	**2395**	**1646**	**211**	**554**	**2411**
		acres	**300.8**	**62.8**	**1159.7**	**1523.2**	**1155.8**	**115.9**	**1719.7**	**2991.4**

Table 3.9 Property Lots Categorized in the Flood Plains

When the data in Table 3.9 is more closely analyzed, 2 conclusions are evident:

1. The probability of additional floodplain development is great. A total of 2411 developable lots exist in urban areas in Clark County, and an additional 2424 exist in rural areas. Many of the rural lots are larger than 5 acres, and therefore are sub-dividable. This means that, in actuality, the number of potential new flood-prone developments is substantially higher than the 4835.
2. Most developable, residentially zoned flood prone lots are large with buildable areas outside of the designated floodplain. This leaves open the possibility of constructing on lots even if sections of them are in the floodplain *without increasing the risk of residential flooding*. Many of the county's larger lots could be subdivided in such a way that development could be constructed outside of the floodplain. Most of these developable yet undeveloped parcels are large enough to accommodate development off of the floodplain through set backs and cluster development.

It is import to remember that floods are part of a natural system and should be considered to be neither good nor bad. Rivers can destroy homes but they can also create land for new ones. Riverine flooding can scour banks as the 1995 flood did along the Salmon River, undermine slopes and cause land to slide. Floods can scour salmon spawning ground, affecting endangered species propagation. The impacts of riverine flooding are not always negative. Flooding may dislodge woody debris, providing enriched habitat. Floods can damage as well as enhance riparian habitat and provide rich soil to farmlands.

Stormwater Problems and Shallow flooding areas

Much of Clark County's southwestern lands are relatively flat with poorly drained soils. During heavy rainstorms, water ponds in these areas. These areas are also among the fast growing land in the county. In 1995, many homeowners suffered water damage that was not directly associated with flooding in a river.

This type of flooding is more than a nuisance to homeowners. Severe structural damage can result from wet shifting soils and damp foundations can create an excellent breeding ground for mildew and related harmful agents. These shallow areas, while causing challenging building environments, often provide excellent natural habitat.

Increased development and the accompanying built land cover is causing increased flood elevations and increased run off in the stormwater system. This was noticed following the 1995 flood.[8] With increased development, the vulnerability of local road and drainage systems would increase from overland flow and blocked culverts. These impacts could isolate some residents from emergency services during a major event.

Capabilities

Clark County has a number of advantages in dealing with flood hazards. This section will detail them.

Flood damage reduction information is readily available through government agencies and via their web sites. Examples include:

- FEMA "880" series worksheets for property owners.
- Flood Hazard Mitigation Handbook for Public facilities.

Following a presidential disaster declaration, there is considerable support for risk reduction. These programs and their implications are often not taken advantage of before permanent repairs are made.

Some of the more significant ones include:

- The Hazard Mitigation Grant Program (HMGP) offers assistance for a wide range of mitigation projects following a presidential declaration. Eligibility is restricted to projects have gone through a comprehensive hazard mitigation planning process.
- Minimal Repair Program often funds risk reduction such as the anchoring of mobile homes
- The Small Business Administration will fund eligible mitigation measure to qualified owners of flood-damaged homes.
- Outreach is available through Disaster Reconstruction Assistance Centers (DRACs), Recovery Information Centers or Hazard Mitigation Teams
- Benefit/Costs Mitigation support is available from FEMA on infrastructure repair. To break the damage-rebuild-damage cycle, FEMA Region 10 is encouraging communities to:
    - Institute, mitigation betterments taking advantage of multi-hazard, multi objective approach when ever possible.

    - To strengthen existing infrastructure and facilities to more effectively withstand the nest disaster
    - To ensure that communities address natural hazards through comprehensive planning
- Following a Federal Declaration, FEMA can support cost effective mitigation on infrastructure and have published a manual on the subject.

State Flood Control Act. The State of Washington prohibits substantially flood prone structures from being rebuilt within the floodway of any watercourse.[9]

National Flood Insurance is available to help rebuild flood-damaged structures whether or not there is a federally declared disaster. The County's Flood Ordinance exceeds the basic requirements of the NFIP in that a 2-foot free board is required for elevated structures. Increased Costs of Construction Insurance can support mitigation measures at the time a flood-damaged structure is repair.

"Project Impact" Program. Through this program, the county has already begun community outreach and education. This program should be continued.

State Growth Management Act and County Critical Areas Ordinance disallow new development in the floodway and other critical areas.

Flood Insurance Rate Maps. The county is currently updating its FIRMs. This process offers opportunities to not only revise the data but to heighten awareness of county flood risks.

Clark County's GIS database. The LIDAR imagery currently being produced in the county, along with revised contour maps and the presents of infrared imagery taken with several days of the 1995 flood peak stages, are excellent data sources for mapping shallow flooding areas. Such an effort would be eligible for funds under the State Flood Control Assistance Account Program (FCAAP), and would not be terribly expensive because of the extensive database already in existence.

FCAAP funds for storm water management program. A more consolidated countywide storm water management program was recommended after the 1995 floods, and FCAAP funds have been secured.

Low Impact Development methods. A new approach to stormwater management is gaining momentum that may offer opportunities for rapidly growing communities such as those in Clark county – that of Low Impact Development (LID).

The Water Quality Board could be helpful in monitoring and implementing strategies.

Increased Cost of Compliance. ICC is an endorsement to the Standard Flood Insurance Policy, applicable to all new and renewed flood insurance policies. This coverage provides for the payment of a claim to help cover the cost to comply with state or community floodplain management laws or ordinances after a flood event in which a building has been declared substantially or repetitively damaged. The current limit is $30,000.

Scenario

A likely flooding event would be one similar the winter of 1995 flood. A rainy and cold winter will be broken by warm weather causing mountain snow to melt and stream runoff to increase. A severe winter storm will accompany the flooding, with massive winds and heavy precipitation.

Creeks will be overwhelmed at the same time that soil is less permeable because of frozen ground and increased human development. The combination will lead to watersheds draining water at overcapacity. Streams will rise above their natural banks, flooding homes and streets in the floodplains. Drainage structures will be overwhelmed, a situation further complicated by blockage from branches downed by the wind. Water will pond and stagnate in flat areas and those having already high water tables. Continued warm, rainy weather in the larger Columbia watershed will result in flood stages along the Columbia River. Water will penetrate the levee system in several areas leading to ponding in low-lying industrial areas.

Unlike 1995, however a future scenario could be more costly. There is increased development in mapped floodplains meaning greater exposure as well as increased flood levels due to increased impervious surfaces. This means that flood stages will be higher. Ponding will occur for longer periods of time and be more extensive, more human debris will block a greater number of culverts. Existing ring dikes that had protected sewage treatment structures and chemical storage structures might fail, impacting downriver wildland sanctuaries and other critical habitat.

More homes will exist on vulnerable slopes, leading to increased numbers of landslides, with potential to destroy homes and damage roadways. The county emergency services response operations could be over-taxed by such an event. Residents, especially those in the more rural parts of the county, consequently experience isolation.

Loss Estimation

Assuming flooding from a relatively major storm, as described above, it is fair to expect flooding along many rivers and streams simultaneously. This could affect many of the homes throughout the county at the same time. The loss resulting from such as event could be significant, though less devastating than the earthquake scenario described above (See Table 3.10).

Loss Summary	
Residential losses:	$91,564,020
Residential losses possible given growth potential:	$167,280,120
Lives affected:	9,932
Damage to drainage systems:	$1,000,000
Operations:	$95,000
Economic loss:	Difficult to calculate; includes immediate damage to commercial and industrial properties (632 exposed lots), damage to utilities (especially wastewater treatment centers located in the floodplain), loss of revenue from workers unable to commute to work (blocked bridges, and overflowed culverts, etc).

Table 3.10: Estimated Losses in Clark County from a Major Flood

The residential losses described here were calculated by first assuming that even a major flood would not affect every developed parcel in the floodplain. This summary conservatively assumes that 10% of development in the floodplain will be affected, or, alternatively, that each parcel will be damaged to 10% of its value. This is a reasonable estimate. Clark County maintains dikes and other flood protective devices that can minimize the effects of flooding. In the 1996 floods, some

homes were completely destroyed and others untouched. Most that were affected by flooding were damaged but not destroyed.

To get the residential loss estimate, the number of developed parcels in the floodplain in the entire county (5847) was multiplied by the average cost of a home in Clark County ($156,600[10]), and the resulting number multiplied by 10% to represent the damage estimate described above. This figure may represent an overestimate. Other sources of information about flood losses show that, in the 1996 floods, $704,564 of property damage was incurred. Additionally, FEMA payments on flood insurance claims from January 1, 1978, to December 31, 2002, totaled $945,784.54[11].

Growth potential losses include all developable lots in the floodplain along with those currently developed (for a total of 10,682 lots potentially exposed to flooding), and follows the same calculation method described above.

Generally, few people die in floods, but many lives are disrupted. Beyond the immediate effects of disruption to life patterns, the longer-term economic effects from loss of property can be devastating. The number above was calculated by multiplying the number of developed lots in Clark County floodplains by the average size of households in the county, 2.6 people[12].

Operations costs and damage to stormwater drainage systems was estimated based on dollar figures associated with the 1996 floods.

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[1] Definition from: The Low Impact Development Center, June, 2003.

[2] U.S. Department of Agriculture, Soil Conservation Service. *Soil Survey of Clark County, Washington.* November, 1972.

[3] Flooding of November 29th, 1996, April 11, 1996 Prepared by Kristine Sposito, E.I.T. and John Milne, P.E. Water Resources Engineer, Clark County Water Quality Division.

[4] Lewis River, East Fork of the Lewis River, Cedar Creek, Chelatchie Creek, Gee Creek, Salmon Creek, Mill Creek, Washougal, Weaver, Burnt Creek and LaCamas Creek

[5] Pacific Power and Light Emergency Action Plan, 2002

[6] Flooding of November 29th, 1996, April 11, 1996 Prepared by Kristine Sposito, E.I.T. and John Milne, P.E. Water Resources Engineer, Clark County Water Quality Division.

[7] This does not necessarily mean that there are nearly 4000 *structures* in floodplains, only that some portion of the *lot* is floodprone.

[8] Flooding of November 29th, 1996, April 11, 1996 Prepared by Kristine Sposito, E.I.T. and John Milne, P.E. Water Resources Engineer, Clark County Water Quality Division.

[9] RCW 86.12

[10] U.S. Census Bureau, 2000.

[11] FEMA National Flood Insurance Policy and Claim Statistic database

[12] U.S. Census Bureau, 2000.

Chapter 3c
Wildfires

Definitions

Wildland fires

This term refers to any uncontrolled burning of grasslands, brush or woodland areas.

Forest fire

Though often used interchangeably with 'wildland fire,' forest fire refers specifically only to the uncontrolled burning of forestland.

Intermix Area

An area susceptible to wildland or forest fires because wildland vegetation and urban or suburban development occur together.[1] An example would be the smaller urban areas and dispersed rural housing in the forested area of northeastern Clark County. Clark County Code defines these areas, and places certain development restrictions on structures built in them. The approximately 11,000 parcels in Clark County within designated intermix areas meet the following criteria[2]:

- Elevation in excess of 500 feet and one or more of the following conditions:
- Slope equal to or greater than twenty-five percent (25%)
- Forest type vegetation
- Outside of an organized fire protection district

Whenever the majority of a parcel lies within the established wildland urban interface/intermix area, the entire parcel shall be included in the area. Figure 3.12 shows which parcels fall in the intermix area.

Background, Wildland Processes

Infrastructure and buildings in interface or intermix areas are especially susceptible to wildfires because they are close to fire fuel sources (the trees and undergrowth that comprise forests), but also because their very presence in the intermix area increases the likelihood that a wildfire will begin. Some of the triggers that can cause fire are natural, such as lightning, but fires are more likely to be caused by human activity. Humans can directly cause fires with careless campfires, sparks from ATVs, or inappropriate disposal of lit cigarettes. Downed electric lines during windstorms can also cause fires.

Wildland fires are influenced by the amount and condition of fuel present, slopes, wind and temperature. Fires advance through the transmission of heat in the form of conduction, convection and radiation. During the day, fires generally travel uphill. Convection currents and radiation ahead of the fire preheat the fuels and air upslope, allowing the fire to expand rapidly. Radiation has an extreme impact when the fire enters a "chimney," or a v-shaped area on a slope, such as a drainage gully. Additionally, south and west facing slopes tend to be warmest and

driest. The situation of heavy dry fuels, on a southwest facing slope with chimneys on a hot day will allow for near explosive expansion of the fire. Wind can strengthen and spread a fire, though large fires can generate their own wind. The heat rising from a large fire will create a thermal column that can rise hundreds or thousands of vertical feet. These vertical columns carry burning embers that are often picked up by prevailing winds and spread. At night, the fire will slow and travel downhill following the cooling airflow.

Fire experts attribute the generally worsening wildfire risk to increases in the presence of dry, hazardous fuel. This has been brought about by an overall decline in forest health. Forests that have been clear-cut become crowded with trees struggling against each other for nutrition, water and sunlight. This can weaken them, making them vulnerable to insects and diseases. In this state, trees burn hot and fast.

Wildfires are most likely to occur between mid-May and October. Any particularly dry period can increase vulnerability. The probability of a forest fire in any one locality on any particular day depends on fuel conditions, topography, the time of year, the past and present weather conditions, and the activities (debris burning, land clearing, camping, etc.) that take place in the vicinity. Wildfires can range from isolated burns affecting a few acres or less to severe events that can burn hundreds of thousands of acres. These large fires usually occur when groups of smaller fires merge.

With the presence of such conditions, lighting on dry fuels, recreational uses, interface development or terrorist acts can all trigger fires.[3] The type of ignition (man-made or natural) should be discounted in evaluating the risk. If the conditions are right in a forest for a major fire, any source of ignition (whether natural or human caused) will bring about the same end results. Mitigation efforts that limit human interaction with fuels can extend the fire cycle or change the location of ignition. However, if the fire cycle is extended and the fuel load is not mitigated, the ultimate fire with burn hotter, move faster, and generate more secondary fires. Such a fire can rapidly overwhelm response capabilities.

Wildfire Hazard in Clark County

2002 marked the 100th anniversary of the Yacolt Burn Fire in Clark County. This fire was the biggest fire in the state's history and a testament to the fire potential along the Columbia Gorge. The Yacolt Burn destroyed 238,900 acres, killed 38 people, and jumped the Columbia River.[4] This human-caused fire illustrates the explosive events that remain a possibility in the County today. Figure 3.13 shows the extent of the area destroyed in the Yacolt Burn.)

Clark County is similar to many areas in Western Washington in its topography and fuel loading. Its slopes are steep in the eastern part of the county, and a wet springtime climate assures that fuel loading is relatively heavy. These are the static conditions, which do not change significantly from year to year, that increase fire risk. However, the dynamic conditions, which may change moment to moment, such as weather, in the county greatly increase the proportional risk. Accordingly, the Washington Department of Natural Resources considers the region to be one of 12 areas in the state at high risk of a major wildland fire with potential for major property loss.[5]

Of particular concern is Camp Bonneville, a former military camp that is remote. Roads provide limited access to the area. Fire suppression in the camp is difficult because it is isolated, but the presence of unexploded ordnance complicates the situation even further.

Small isolated fires causing little damage occur several times a year in Clark County, and major conflagrations occurred three times in the first 3 decades of the 20th century. Natural fires the size of the Yacolt Burn can occur at least once every 200 to 500 years. As is evident from the map,

fires can, and have, begun just about anywhere in the county, but are most common in the area now known as the intermix area.

The amount of warning that people will have before a Clark County fire threatens is variable, but is generally sufficient for evacuation to occur in most, but not all, developed or developing areas.

Secondary Hazards

Wildland fires can generate a range of secondary effects, which in some cases may cause more widespread and prolonged damage than the fire itself. Fires can cause direct economic losses in the reduction of harvestable timber and the more indirect economic losses in reduced tourism. Wildland fires cause the contamination of reservoirs, destroy transmission lines and contribute to flooding. Landslides can be a significant secondary hazard of wildfires. Wildfires strip slopes of vegetation, exposing them to greater amounts of rain and run-off. This in turn can weaken soils and cause failures on slopes. Major landslides can occur several years after a wildfire.

In addition to landslides, the following are secondary effects are possible. Rehabilitation efforts after a fire occurs can reduce but cannot eliminate them:

- **Damaged Fisheries:** Critical trout fisheries throughout the west and salmon and steelhead fisheries in the Pacific Northwest can suffer from increased water temperatures, sedimentation, and changes in water quality and chemistry.
- **Soil Erosion:** The protective covering provided by foliage and dead organic matter is removed, leaving the soil fully exposed to wind and water erosion. Accelerated soil erosion occurs, causing landslides and threatening aquatic habitats.
- **Spread of Invasive Plant Species:** Non-native woody plant species frequently invade burned areas. When weeds become established, they can dominate the plant cover over broad landscapes, and become difficult and costly to control.
- **Disease and Insect Infestations:** Unless diseased or insect-infested trees are swiftly removed, infestations and disease can spread to healthy forests and private lands. Timely active management actions are needed to remove diseased or infested trees.
- **Destroyed Endangered Species Habitat:** Catastrophic fires can have devastating consequences for endangered species. For instance, the Biscuit Fire in Oregon has destroyed 125,000 to 150,000 acres of spotted owl habitat.
- **Soil Sterilization:** Topsoil exposed to extreme heat can become water repellant, and soil nutrients may be lost. It can take decades or even centuries for ecosystems to recover from a fire. Some fires burn so hot that they can sterilize the soil.

Vulnerabilities

Intermix Area Land Uses

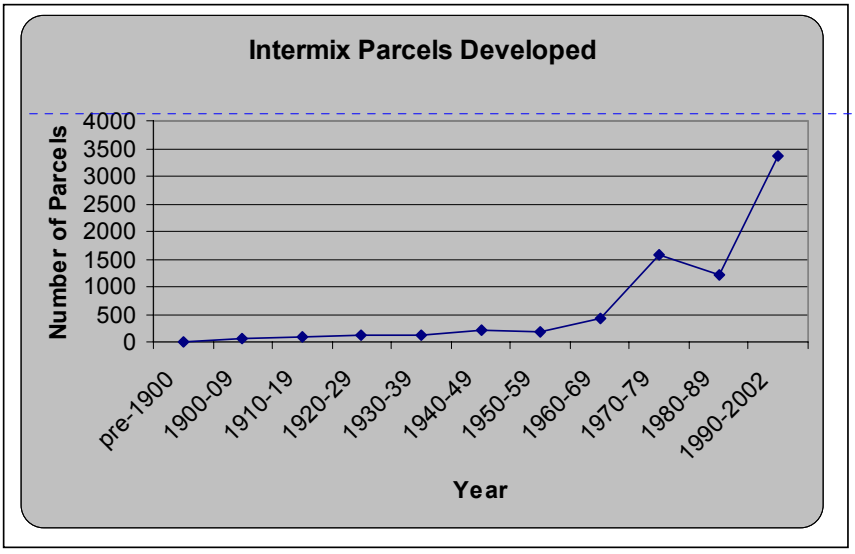
The most vulnerable areas in Clark County are the intermix areas. Clark County has experienced extensive growth in its intermix areas, a trend which is likely to continue. Table 3.11 below[6] summarizes the types and numbers of residential structures present in the intermix zone in Clark County.

Comment: Hey Glenn – is this data still ok? If not, is there a replacement for it?

Type of Residential Unit	Number
Single family	5853
Mobile Home	1634
Apartments and Condominiums	29
Multi-family homes	21
Other	3
Total	**7540**

Table 3.11: Types of Residential Structures in Intermix Area

Parcels in the intermix area have developed very rapidly within the last 12 years (about 8.2% per year for the last 12 years), as is evident in Figure 3.14 below. Projections confirm that this trend is likely to continue. If fire suppression capabilities are not increased proportionally with the population, lives and homes will be endangered. Additionally, new homes must be accessible to fire fighting equipment, built with fire resistant materials, and include landscape design that discourages the spread of fire.



Comment: We should have a chart which gives us all of these numbers.

Figure 3.14: Intermix Development by Parcel and Year

Clark County code now incorporates many of these elements. As of 1993, all new subdivisions must have adequate access, connecting bridges, turn around areas and driveway widths to allow for fire suppression equipment.[7] Current Clark County code requires that development and construction be designed, located and constructed to minimize the possibility of wildland fires involving structures, as well as to reduce the possibility that structural fires will ignite a wildland

fire. Code incorporates the standards included in the National Fire Protection Association's Protection of Life and Property from Wildfire standards (NFSP-299).[8] These standards require homes to have appropriate:

- Set backs from slopes
- Defensible space
- Vehicular access
- Roofing materials
- Siding materials
- Balconies and porches
- Eves and overhangs.
- Access to water

A major vulnerability issue, then, is with subdivisions platted and developed before fire code was adopted. Water supplies may be limited within these pre-ordinance subdivisions. It is particularly troubling for homes on wells. Many of these may also have access problems, including inadequate ingress and egress and insufficient roadway width and road grade to enable evaluation or fire suppression.

Table 3.12 below summarizes the development timeline in relation to fire code implementation, and is useful for determining the number of parcels potentially at risk. Nearly 5000 parcels were developed before code existed to protect them; many of these parcels are shown in the map above depicting isolated subdivisions.

Parcels in Intermix	Number	Meet code?
Developed, pre-1993	4,800	No
Developed, post-1993	2,740	Yes
Undeveloped	3,332	Will meet
Total Intermix Parcels	10,872	N/A

Table 3.12: Number of Parcels in Intermix that Meet Code

Development that has occurred after 1993 is not invulnerable to fire, though, just because it meets development code. Any development in the intermix zone can potentially be exposed to fire, and the number of homes constructed in vulnerable locations is increasing rapidly.

As is evident in Table 3.12, there is a significant amount of development that is likely to occur in the intermix area. As of 2002, over 4000 buildable, undeveloped parcels existed within intermix areas. The development of these parcels could greatly increase the life and property exposed to the threat of wildland fires. At the same growth rate the area experienced between 1990-2002 (about 8% per year), an additional 733 people and $43 million in property will exist in the intermix area *next year* (in 2004).[9] If every parcel were developed, 8896 new people could live in the intermix zone. This estimate should be considered conservative, in part, because it assumes that no new lots are created through subdivision. There are many undeveloped buildable lots of greater than 10 acres that could possibly be subdivided, increasing this projection by 2 or 3 times.

According to recent research, most residential areas destroyed in wildfires are not ignited by advancing flames of a large crown fire, but rather from embers falling on a non-resistant roof, radiant heat igniting a curtain or pine needles, or even a forgotten gas can near a home. Without these conditions present, a fire can burn quickly through a development without actually igniting structures. This research emphasizes the importance of fireproofing and "ring of safety" approaches advocated by such programs as FireWise. Small fuel removal efforts and building material choices around the home can save an entire subdivision from destruction.

Capabilities

The following is a list of programs and requirements already in place that can help to reduce the risk from wildfire in Clark County.

County regulation. The county passed its first Uniform Fire Code on September 02, 1976, and amended it on May 1, 1993, to require all development and construction be designed, located and constructed to minimize the possibility of wildland fires involving structures, as well as structural fires that might affect wild lands. Clark County adopted NFPA 299, Protection of Life and Property from Wildfire by reference (Title: 15.13.060).

State Grants. The county has received Washington DNR "Community Action Planning Grants" to:

- Study evacuation routes (SR 504-US12 Feasibility Study)
- Evaluate alternative water systems (Yacolt Waste Water Feasibility Study)
- Conduct wildland fire surveys in Eastern Clark County (Yacolt Wildfire Risk Surveys in the Interface)

Federal Grants. The County has received National Fire Plan Grants for fuel reduction.[10] The communities of Yacolt, La Center, and Ridgefield have received national Fire Plan[11] funds to create private and public partnerships to reduce the risk by September 2002, of some of the Southwest Washington most at risk homes. The goal is to create model neighborhoods and to develop a "critical mass" of FireWise homes that inspire other homeowners to take impendent prevention steps. Grant funded crews clear brush, trim trees, and widen driveways for fire engines. In return homeowners agree to keep the brush trimmed for the next 10 years.

Camp Bonneville. Camp Bonneville has a suppression plan developed by the Department of Defense.

Fire damage reduction information. Wildland fire risk reduction information is readily available through government agencies and via their web sites.

- The FEMA "880" series worksheets for property owners is one example.
- FireWise has material available on its web site at and throughout the community.

Support following a presidential declaration. There is considerable support for risk reduction measures following a federal declaration. Some of the more significant programs include:

- The Hazard Mitigation Grant Program (HMGP) offers assistance for a wide range of mitigation projects following a presidential declaration. Eligibility is restricted to projects have gone through a comprehensive hazard mitigation planning process.

- The Minimal Repair Program often funds risk reduction by replacing damaged materials with fire resistant replacements.
- The Small Business Administration will fund eligible mitigation measures to qualified owners of damaged homes.

Benefit/Costs Mitigation support is available through FEMA for infrastructure repair. Eligible items may include under-grounding utilities, removing vegetation, rebuilding damaged facilities with fire resistant materials.

Outreach:

- Outreach is available through Disaster Reconstruction Assistance Centers (DRACs), Recovery Information Centers or Hazard Mitigation Teams.
- Clark County is a "Project Impact" Community. This program has already instituted outreach programs, an effort that should be continued.
- The State of Washington DNR has regional representation that has a history of working with intermix communities.
- Local fire districts have dispensed information, conducted workshops and assessed the risks to private property.
- The FireWise program is a well-known and effective public education campaign.

Scenario

With increased intermix development, a wildland fire in the Clark County foothills has the potential to cause even greater damage than the historic Yacolt Burn. A 21st century firestorm could burn an area approaching the size of the Yacolt Burn, but because of increased development in the area, it would destroy much more property and put more lives at risk.

A major conflagration might begin with a wet spring, adding to the fuels that are already present on the forest floor. Flashy fuels will build throughout the spring. The summer may see the onset of insect infestation. A dry summer could follow the wet spring, exacerbated by dry hot Chinook winds. The Labor Day holiday inevitably brings many hikers and campers to the area. Careless campfires or a tossed lit cigarette, or a sudden lighting storm would trigger a multitude of small isolated fires. Some fires could easily be located in Camp Bonneville.

The embers from these smaller fires could be carried miles by the hot, dry prevailing winds. The deposition zone for these embers will be deep in the forests and intermix zones. Fires that start in flat areas will move slower, but wind will still push them. It is not unusual for a wild fire pushed by wind to burn the ground fuel and later climb into the crown and reverse its track. This is one of many ways that fires can escape containment, typically during periods when response capabilities are overwhelmed.

These new small fires would most likely merge. Suppression resources will be redirected from protecting the natural resources to saving the more remote subdivisions.

The worst-case scenario in Clark County would probably coincide with an active fire season in the entire American west, spreading resources thin. "Hot shot" teams will be either exhausted or committed to fighting conflagrations occurring in other areas. They may well be unavailable to assist Clark County. Many Federal assets will likely be responding to other fires that started earlier in the season. While local fire districts will be extremely useful in the urban intermix

areas, they have limited wildfire capabilities or experience, and they will have difficult time responding to the ignition zones. Additionally, starting with the 2003 fire season, air tanker support has been cut by one-third.

Even though the existence and spread of the fire is well known, it may not be possible to respond to it adequately. Thus an initially manageable fire can become very significant before meaningful resources are dispatched.

To further complicate the problem, heavy rains could follow, causing flooding, landslides and releasing tons of sediment into rivers, permanently changing the floodplains of the County and damaging sensitive habitat and riparian areas. Such a fire followed by rain could release millions cubic yards of sediment into streams for years creating new floodplains and changing exiting ones. With the forests removed from the watershed, discharges could easily double. Floods that could be expected every 50 years may occur every couple of years. And, with the streambeds unable to carry this increased discharge because of increased sediment, the floodplains and floodplain elevations would increase. Construction along Clark County rivers has been increasing proportionally faster that that of the county as a whole. The number of homes subject to flooding would increase substantially in a post wildland fire situation.

As many as 2000 homes might be destroyed in such a fire, which would represent approximately $312 million[12] in damage. And, with fire suppression costs easily exceeding several million, coupled with tens of millions in losses to bridges and roads, the total direct costs of such a fire could exceed $500 million (See Table 3.13). Indirect and longer-term economic losses are difficult to predict, but could ultimately double the price tag for such an event.

Loss Estimation

Loss Summary	
Residential losses:	$1,156,491,000
Residential losses possible given growth potential:	$1,807,633,800
Lives affected:	19,193
Economic loss:	Difficult to calculate; includes immediate damage to commercial and industrial properties (11 exposed lots), damage to utilities (electrical lines and substations), loss of revenue from workers unable to work, and the great expense often incurred when fighting a fire.

Table 3.13: Estimated Losses in Clark County from Wildfires

In the worst-case scenario described above, residential losses could be very significant; however, even in this scenario, the entire area that is potentially exposed to the hazard will not experience the fire. The residential loss number above, then, represents the dollar amount associated with all property exposed to wildfire hazards rather than the dollar figure associated with any single fire. It was calculated by multiplying the number of developed parcels in the intermix area (7382) by the average cost of a home in Clark County ($156,600[13]).

There is little doubt that the potential for major losses in the intermix zone is growing. There are a total of 4158 buildable residential parcels in wildfire-prone locations. There are also 64 parcels

zoned for either commercial or industrial parcels. The loss of these types of structures can have wide-ranging effects for communities if they are major employers in the area.

Generally, few people die in wild fires because warning time is sufficient to allow for evacuation. However, many lives are disrupted. Beyond the immediate effects of disruption to life patterns, the longer-term economic effects from loss of property can be devastating. The number above was calculated by multiplying the number of developed lots in Clark County intermix zones by the average size of households in the county, 2.6 people[14].

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[1] Slaughter, R., editor. 1996. *California's I-Zone - Urban/Wildland Fire Prevention & Mitigation*, State of California, Resources Agency, California Department of Forestry & Fire Protection, and California State Fire Marshal, Sacramento, CA 95823-2034, 301 p.

[2] Clark County Code, Title 15.13.030, Geographic Areas Included in Intermix

[3] Wildfires have been started deliberately and maliciously in California, and in Arizona (the 2002 the Showlow fire is an example).

[4] The normal, natural return interval for a Yacolt type burn would be from 200 to 500 years. The Yacolt burn was, however, was not naturally set.

[5] Clark County Fire District 3, DNR "Community Planning Grant" award document.

[6] GIS product developed from overlaying County identified intermix zones with developed land use.

[7] Clark County Code, Title 15.13.060, Access in intermix areas.

[8] Clark County Code, Title 15.13.050, General Requirements for intermix areas.

[9] This analysis assumes 2.67 people per household, and a median household value of $156,000. These are the averages for Clark County as a whole according to the 2000 U.S. Census.

[10] Washington National Fire Plan -- Washington State Department of Natural Resources, *A Progress Report on the National Fire Plan in Washington State,* 2002.

[11] Clark County Fires Districts 2, 3 9, 10, and 13 have received NFPA grants to remove hazardous fuels, thereby minimizing the risk of wildland fires and helping to restore health to fire-adapted ecosystems.

[12] Based on the 2000 U.S. Census median home cost in Clark County: $156,600.

[13] U.S. Census Bureau, 2000

[14] U.S. Census Bureau, 2000.

Chapter 3d
Severe Weather

Severe Weather in Clark County

Clark County is susceptible to several severe storm hazards, including ice, snow, windstorms and tornadoes. While severe local storms have seldom caused death or serious property damage, they frequently caused major utility and transportation disruptions. Severe local storms occur somewhat infrequently, and are monitored well by NOAA. However, it is possible that they may occur more rapidly or with greater severity than predicted. Additionally, warning systems such as weather radio may not be available in all part of the county.

Though some areas along the Columbia Gorge experience more frequent and severe high winds, storms occur all over Clark County. A single storm may affect a vast area of land and all of the population within it. Because storms often significantly affect utility and transportation systems, outages are a frequent result of storms and ingress and egress may be limited. Consequently, the more isolated areas of the county may experience greater effects from storms. Severe local storms significantly impact driving conditions on roads, and power lines that can cause isolation. They can also hinder police, fire, and medical responses to urgent calls.

Snowstorms

Snowstorms are a more frequent occurrence in the higher elevations of the eastern part of Clark County, but they can occur in the lower elevations as well. In general, the Cascade Mountain Range acts as a barrier to cold air developing in the eastern part of the state, reducing the likelihood of snowstorms in Clark County. However, cooler air can enter the valley through low points or advance downriver through the Columbia Gorge. When this occurs, it can cause snowstorms in even the lower elevations of the county. Typically, the snow melts rapidly as a result of the warmer air in the valley.

Past weather event data from NOAA has shown that snowstorms have occurred relatively infrequently, approximately six times since January of 2000. January typically has the greatest snowfall, with an average of 3 to 4 inches. Though storms vary in their severity, typical snowstorms have approximately 1 to 4 inches of accumulation. Average snowfall for populated areas, valleys, and lower elevations in Clark County is about 7 inches a year.

Wind Storms

In Clark County there are several sources of windstorms. Southwesterly winds are associated with strong storms moving onto the coast from the Pacific Ocean. Southern winds parallel to the Cascade Mountains are the strongest and most destructive winds. Strong eastern winds originate from the Columbia Gorge when high atmospheric pressure is over the Upper Columbia River Basin and low pressure is over the Pacific Ocean. The narrow point of the gorge acts as a funnel, concentrating the intensity of the winds. Strong winds are generated at the outlet of the gorge near Camas and Washougal. Windstorms tend to damage ridgelines that face into the winds. NOAA has reported six windstorms since January of 2000, with wind speed varying from 45 to 95 knots.

Ice Storms

Ice storms occur when rain falls from warm moist upper layers of the atmosphere into a colder, drier layer near the ground. The rain freezes on contact with the cold ground and accumulates on exposed surfaces. Since January of 2000, NOAA has reported no ice storms in Clark County.

Tornadoes

Clark County also has some susceptibility to another type of severe local storm: tornadoes. Tornadoes are characterized by funnel clouds of varying sizes that generate winds as fast as 500 miles per hour. They can affect an area of ¼ to ¾ of a mile, with the path varying in width and length. Tornadoes can come from lines of cumulonimbus clouds or from a single storm cloud. They are measured using the Fujita Scale ranging from F0 to F6.

Six documented tornadoes have occurred to date in Clark County, all of them between 1951 and 1989. Their severity ranged from an F0 to an F3 on the Fujita scale. An F0 is a gale tornado that has speed ranging from 40 to 72 mph. Damages from this level of tornado are typically breaks in tree branches and damages to sign boards. An F3 tornado is considered a severe tornado that has speeds ranging from 158 to 206 mph. F3 tornadoes can uproot trees and tear the roofs and walls from even well-built houses. The April 5, 1972 tornado in Vancouver had a path 9 miles long and caused 300 injuries and 6 deaths. Table 3.14 below provides more information about past tornado events in Clark County.

Date	Location	Severity
October, 1951	Battle Ground	F0
August 26, 1953	Ridgefield	F0
April 5, 1972	Vancouver	F3
December, 1974	Camas	F0
October 13, 1984	Woodland	F1
June 29, 1989	La Center	F1

Table 3.14: Past Clark County Tornado Events
Source: NOAA files

There is typically little warning time for tornadoes. Events are difficult to predict and generally occur suddenly. However, storm tracking, the use of weather radar and visual observation systems have been fairly effective in providing short-term warning in tornado-prone regions of the U.S. During tornado events a major concern are the high-density low elevation areas in Clark County. Houses and buildings located in lower elevations of Clark County are susceptible to damage from tornadoes. Power and communication lines are also a major vulnerability. Roads and railroads can be blocked by debris following a tornado.

Secondary Hazards

The most significant secondary hazards to severe local storms are floods, landslides and electrical hazards (fires) from downed power lines. Rapidly melting snow combined with heavy rain can overwhelm both natural and man-made drainage systems, causing overflow and property destruction. Landslides occur when the soil on slopes becomes oversaturated and fails. Both landslides and floods are covered in detail in other sections of the plan.

Vulnerability and Exposure

Severe local storms will have significant impacts as Clark County continues to experience a rapid residential growth rate. In general, every household and resident in the county is likely to be exposed to severe weather, however some are more likely than others to experience isolation as a result. Those residing in the intermix zone may have the greatest vulnerability to isolation from storms. These are defined in county code to include areas that meet the following considerations[1]:

Elevation in excess of 500 feet, and one or more of the following conditions:

1. Slope equal to or greater than 25%
2. Forest type vegetation
3. Outside of an organized fire protection district

Because they are in steep areas, roads may be difficult to navigate when snowy or icy. Forest vegetation may block roadways after high winds. Perhaps most importantly, because these homes are outside of an organized fire district, response times during an emergency may be lengthened. A total of 7540 residential units meet the criteria described above, and as can be seen from Figure 3.12, many of these parcels are also in higher elevations more likely to experience poor weather.

Another specific population of concern is the elderly. A notable portion of the population is elderly; approximately 32,800 people (nearly 10% of all residents of Clark County) are over 65 years of age. In general, these populations may be more likely to require medical or other emergency attention as a result of isolation. Elderly populations seem to be distributed relatively evenly throughout the county. The U.S. Census reports that the average age in each of the jurisdictions varies by no more than 1 year from the average age of the county as a whole.

Man-made and infrastructure vulnerabilities

- Severe local storms may cause trees or tree limbs to fall as a result of freezing rain or high winds. This debris can damage homes and buildings and break windows.
- *Roads/Railroads*: High winds can cause significant damage to trees and power lines, disrupting ingress and egress on roads with obstructing debris. Additionally, snowstorms will significantly impact the transportation system and the availability of public safety services. Of particular concern are roads providing access to isolated areas and to the elderly.
- *Economic systems*. Prolonged obstruction of major routes due to snow, debris, or floodwaters can disrupt the shipment of goods and other commerce. Large and prolonged storms can have negative economic impacts for an entire region.
- *Power and communication lines* – Ice and severe windstorms can create serious impacts on power and above ground communication lines. Freezing of power and communication lines can cause them to break, disrupting both electricity and communication for households. They can also break as a result of falling trees. Clark Public Utilities cites that 18% of all power outages in the county are the result of downed trees and tree limbs. This can result in isolation.

- *Water and Sewer lines* – Severe local storms can cause water and sewer lines to freeze, which may crack pipes. This could result in a loss of potable water to households or exposed sewage causing public health hazards. However, extreme and prolonged freezing weather is required to cause underground pipes to crack, which is not likely to occur in Clark County. Above ground pipes leading to and from individual homes are more likely vulnerabilities than large mainlines.

Natural System Vulnerabilities

Severe local storms can have significant effects on the environment. Heavy rains will cause the ground to become saturated, and rivers and streams to rise. This will result in the potential for flooding and landslides. Additionally, snowmelt after snowstorms can cause riverine flooding, which has the potential to damage riparian habitat.

Human Vulnerabilities

Particular vulnerable populations are the elderly, people with life-threatening illnesses and residents living in areas that are isolated from major roads. Power outages can be life threatening to those dependent of electricity for life support. Isolation of these populations is a significant concern.

Capabilities

The county and its jurisdictions have several advantages when dealing with severe storms.

- Priority routes for snow removal are in existence throughout the county. These roads are cleared first to assure that navigable routes through and between jurisdictions exist.
- In the areas most subject to isolation (the intermix areas described above), people are generally quite self-sufficient. Because they experience severe storms and the accompanying isolation with relative frequency, they are accustomed to listening for warnings and tend to have a 72-hour supply of food and water on hand. Many also own generators.[2]
- County or regional emergency command centers can be activated to coordinate incoming emergency calls.

Scenario

Although severe local storms are infrequent, impacts can be significant, particularly when secondary hazards of flood and landslide occur in tandem. A worst-case event would involve prolonged high winds during a snowstorm accompanied by freezing temperatures, followed by warmer weather and continued rain. Such an event would have both short-term and longer-term effects. Initially, schools and roads would be closed due to snow and downed tree obstructions. Power outages would be common throughout the county. In the more rural areas, some subdivisions in unincorporated areas could experience limited ingress and egress. Later, as the weather warms and snow turns to rain, the sudden run-off could produce flooding, overtopped culverts with ponded water on roads, and landslides on steep slopes. Flooding and landslides could further obstruct roads and bridges, further isolating residents.

This combination in November 1995, resulted in flood damages to roads and bridges, dikes and storm drainage systems, residences, businesses and farms throughout Clark County. Power lines

were down throughout the county. Total damage was estimated at about $25 million. Rainfall was measured at approximately 10 inches above average for that period.

Secondary hazards – It is likely that several secondary hazards such as flooding or landslides will occur during or after storm events in isolated areas.

Loss Estimation

Losses from severe weather events can be difficult to calculate, because they often include the indirect costs of missed work, closed businesses, short-term losses of electrical power, and the sum of many of the more individual-scale results of storms (car accidents, property damage from leaky roofs or frozen pipes, etc.). The entire population of Clark County (345,238 people[3]) is likely to be affected by a severe storm at some point during any given year with relatively insignificant consequences.

However, some severe weather events can be quite expensive. Past events provide some good clues about the costs associated with severe weather in the county. Though tornados happen infrequently, when they do occur, relatively significant losses of life and property can result. Heavy snow and thunderstorms can also cause significant damage. Table 3.15[4] below highlights the range of property damage figures that can be expected as a result of severe weather events.

Location	Date	Storm Type	Death	Injuries	Property Damage
Clark	4/5/1972	Tornado	6	300	$25 million
Clark	10/13/1984	Tornado	0	0	$25,000
Clark	6/29/1989	Tornado	0	1	$3,000
Clark	2/18/1993	Heavy Snow	1	0	$500,000
Vancouver	5/31/1997	Tornado	0	0	$10,000
Hockinson	6/21/1997	Lightning	0	0	$10,000
Clark	1/11/1998	Ice Storm	0	0	$250,000
Clark	2/5/1999	High Wind	0	0	$25,000
La Center	8/4/1999	Lightning	0	0	$15,000
Battle Ground	5/11/2000	Tornado	0	0	$10,000
Vancouver	6/27/2001	Thunderstorm with wind and hail	0	5	$25,000

Table 3.15: Severe Weather Property Damage Estimates

[1] Clark County Code, Title 15.13.030, Geographic Areas Included in Intermix

[2] Anecdotal information, Yacolt Jurisdiction Input meeting, 6.6.03

[3] U.S. Census Bureau, 2000

[4] National Climatic Data Center, National Oceanic and Atmospheric Administration Satellites and Information, National Environmental Satellite, Data, and Information Service.

Chapter 3e
Hazardous Materials

Background, Hazardous Materials

Hazardous materials (sometimes referred to as 'hazmat') by definition have chemical, physical, or biological natures that threaten life, health or property when released. Releases occur through spills, leaks, emissions of toxic vapors, or any other process that enables the material to escape its container and enter the environment. There are several properties or qualities that make a material hazardous, including explosivity, flammability, combustibility, corrosiveness, chemical reactivity, toxicity, and radioactivity.[1] Hazardous materials can also exhibit qualities of a biological agent.

Hazardous materials can include chemicals used in manufacturing, household chemicals, crude oil and petroleum products, pesticides, herbicides, fertilizers, paints, medical wastes, radioactive materials and a host of other substances. They do not include[2]:

- Food, food additive, color additive, drug, or cosmetic regulated by the FDA
- Substances present as a solid in any manufactured item to the extent that exposure does not occur under normal conditions of use;
- Substances used for personal, family, or household purposes
- Substances that is used in a research laboratory or a hospital or medical facility under the direct supervision of a technically qualified person
- Substances used in routine agricultural operations or a fertilizer for sale

Hazardous material incidents that result in a release can cause significant damage to both humans and the environment. The impact of hazardous materials incidents depends on the quantity and physical properties of the chemical. It depends on the type of release that occurred and its proximity to population and businesses.

In 1986, Congress enacted the Emergency Planning and Community Right-to-Know Act (EPCRA) as part of the Superfund Amendments and Reauthorization Act (SARA) as a result of public concern about hazardous material and chemical accidents. This act, known as Title III, establishes requirements for federal, state, and local governments as well as for industry regarding emergency response planning and the public's right to know about hazardous chemicals in their community. The State of Washington has adopted the Federal Title III law and regulations (WAC Chapter 118-40). Title III requires that all facilities or businesses that have reportable quantities of certain chemicals must complete a Tier II Emergency and Hazardous Chemical Inventory report. Each facility does this for each type of Tier II chemical that is present. This must be given to the Local Emergency Planning Committees (LEPC), the local fire department and the Washington Department of Ecology.

Hazardous Materials in Clark County

Hazardous materials releases in Clark County originate from both fixed sites (facilities that hold hazardous materials on-site) and transit-related operations (referring to releases that occur during the transportation of hazardous materials). In Clark County, hazardous materials are transported by air, rail, truck, ship, and pipeline. All fixed site locations are reported as Tier II facilities. In Clark County, paper mills, high-tech industry, medical facilities, schools, metal plating and finishing, utility companies, cold storage facilities, fuel-related industries, communication industry, and chemical distributors are all among the Tier II reporters.

Over 78% of actual hazardous materials incidents occurred at fixed facilities with the remaining occurring in transit. In the year 2001, 103 companies, departments, and agencies in Clark County reported a total of 135 of sites and locations and listed 1074 chemicals, compounds, substances that are under Tier II. Sixty of the facilities listed a total of 147 chemicals listed by the EPA as Extremely Hazardous Substances. Extremely Hazardous Substances are those materials that may cause irreversible damage or death to people, or harm the environment when released outside their intended use. Figure 3.15 shows Tier II Reporters and number of Extremely Hazardous Substances by city.

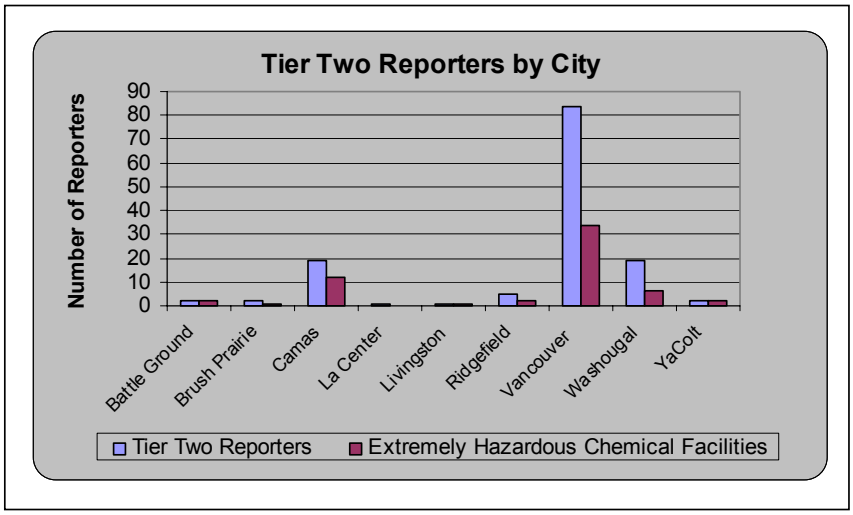

Figure 3.15: Tier II Reporters by City - 2001

The most significant concentration of hazardous materials in Clark County is in the industrial areas near the Ports of Vancouver, Camas and Washougal. Transportation of hazardous materials by air, rail, truck, ship and pipeline are also a risk.

The Hazardous Substances Emergency Events Surveillance (HSEES) program, sponsored by the Agency for Toxic Substance and Disease Registry (ATSDR), tracks emergency releases of non-petroleum hazardous substances. The Washington Department of Health (WDOH) has collected specific data on these incidents and their associated injuries. Incidents that are included in the data meet the following criteria: (1) the amount of substance that was released, or that might have been released, needed (or would have needed) to be removed, cleaned up, or neutralized according to federal, state, or local law; or (2) there was only a threatened release of a

substance, but this threat led to an action could have affected the health of employees, responders, or the general public.[3] Table 3.16 shows the total number of fixed and transportation hazardous material incidents that have occurred in Clark County from 1993-2001.

YEAR	1993	1994	1995	1996	1997	1998	1999	2000	2001	TOTAL
Transportation	5	6	11	1	6	5	5	1	5	45
Fixed Facility	18	15	17	17	19	12	23	21	19	161
Total Events	23	21	28	18	25	17	28	22	24	206

Table 3.16: HSEES Incidents in Clark County by Year

In Clark County, the major concern for hazardous materials is their potential release as a result of another hazard event, such as to an earthquake or a flood. Many of the facilities containing hazardous materials are located in the industrial areas at the Port of Vancouver and Camas/Washougal. Several of these facilities are built on are NEHRP soils type E and F, indicating a potential for liquefaction, amplified shaking, and possible failure during an earthquake. Flooding in these areas can also cause a release of hazardous materials from barges or containment areas into the surrounding environment.

There is generally little or no warning time to mobilize response prior to a hazardous material release, but dissemination of information can be rapid. The amount of time from release to response varies depending on accessibility of location and severity of incident.

The potential impact of a hazardous material spill or release is dependent on the nature of the material, conditions of the release, and area involved. Releases may be small and easily handled with locally available emergency response resources, or they may rise to the devastating level with immediate effect and long-term public health and environmental consequences.

Secondary Hazards

Hazardous material incidents can produce a variety of secondary effects. Fires resulting from hazardous materials releases are the most significant secondary hazard. Fires will usually result from releases caused by earthquakes. These will most likely occur in port and commercial districts, where the majority of hazardous materials are stored, and will cause direct economic losses.

Hazardous material incidents will have a significant effect on the environment. Releases into the environment have the potential to significantly damage soils, water quality, wildlife habitat as well as vegetation. Harm to water systems such as watersheds and fisheries, as well as critical habitat for threatened or endangered species, is likely. Processes to clean up hazardous material releases are costly and time consuming, resulting in severe environmental and economic impacts.

Vulnerabilities

A hazardous material incident will generally impact a relatively small area, but if that area is a high-density urban location or a critical wildlife habitat, the vulnerabilities could be significant. As Clark County continues to grow and attract new high tech industry to the area, the amount of hazardous materials at both fixed sites and in transit will increase. As such, hazardous materials incidents may also increase.

The most vulnerable areas are the areas surrounding the Port of Vancouver and Camas and Washougal. Hazardous material containment areas and facilities are in abundance at both the

Port of Vancouver and Camas/Washougal. There are several that are within 500 feet of the Columbia shoreline. The Columbia River near and upstream of Vancouver is vulnerable to a hazardous materials release with the potential for destruction of habitat and wildlife. The Port of Ridgefield also historically contained hazardous materials and is currently contaminated with Phenobarbital. This material is highly toxic and has the potential to leach into the Columbia River if the Port of Ridgefield were flooded. This would again cause environmental damage. Figure 3.16 displays the location of Tier II Reporters in Clark County as of 2000.

A Hazardous Material Commodity Flow Study was completed in Clark County in 1998.[4] This document analyzed transit flow of hazardous materials throughout the county. The main local highways and roads that are used to transport hazardous materials in Clark County include I-5, I-205, SR 14, SR 500, SR 503, Mill Plain and Fourth Plain boulevards. Approximately 4% of the commercial truck traffic in Clark County transports hazardous materials. Approximately 3% is carried on I-5. In 1998, 7% was transported on Fourth Plain Boulevard. Truck traffic now uses Mill Plain Boulevard, which passes near the Vancouver city and county government complex. Homes, businesses and critical habitats along these highways and roads are vulnerable to a hazardous materials incident.

The most common hazardous material transported by rail in 1997 is chlorine, which is considered an extremely hazardous substance. An additional concern associated with railroads cars is the residue of hazardous chemicals left in them after emptied, which can be flammable and have the potential to conflagrate. A total of 20,803 loaded railroad cars contained hazardous materials and 19,513 cars contained residue for the entire county. Any homes, businesses and critical habitats along this corridor are vulnerable to a hazardous material incident involving a railway.

Olympic Pipeline Company has 14.5 miles of underground pipe that transports refined petroleum products from refineries in northwest Washington to Portland, Oregon. Williams Pipeline Company has a 58-mile natural gas pipeline that bisects the County both north-south and east-west. Significant areas along these corridors are vulnerable to a pipeline break containing petroleum, which could also result in major explosions and fire. Populations, man-made structures and habitats are vulnerable to this.

From 1993 to 2001, a total of 206 hazardous material incidents (not including petroleum related incidents) were reported to HSEES. Table 3.17 shows the injuries that occurred related to these incidents.

YEAR	1993	1994	1995	1996	1997	1998	1999	2000	2001	TOTAL
Events w/injuries	4	3	3	3	1	4	7	10	6	41
Total injured	57	6	4	11	2	14	14	25	67	200

Table 3.17: HSEES Incidents with Injuries

Figure 3.17 and 3.18 display the distribution of the age of people injured during hazardous material incidents and the category of the person injured from 1993 to 2001. The ages of those injured are relatively well distributed, though a significant number of young children have been injured. The majority of injuries occurred to employees, suggesting the importance of workplace safety measures.

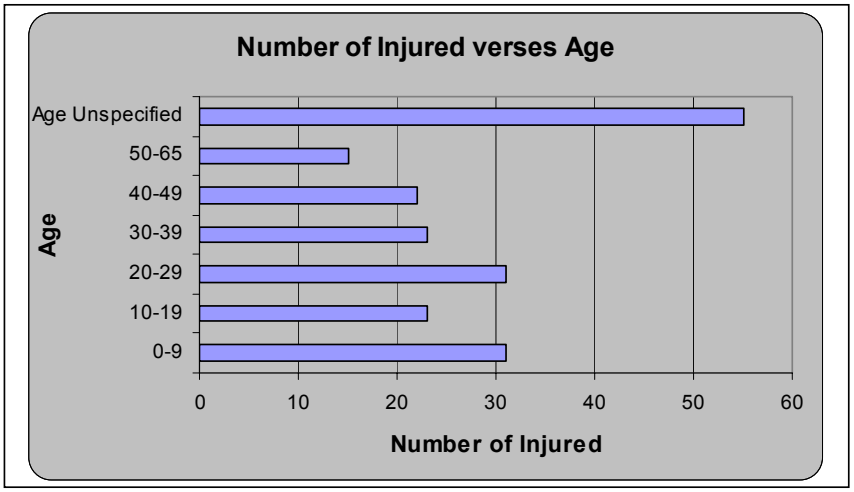

Figure 3.17: Age of Persons Injured in Hazardous Materials Releases

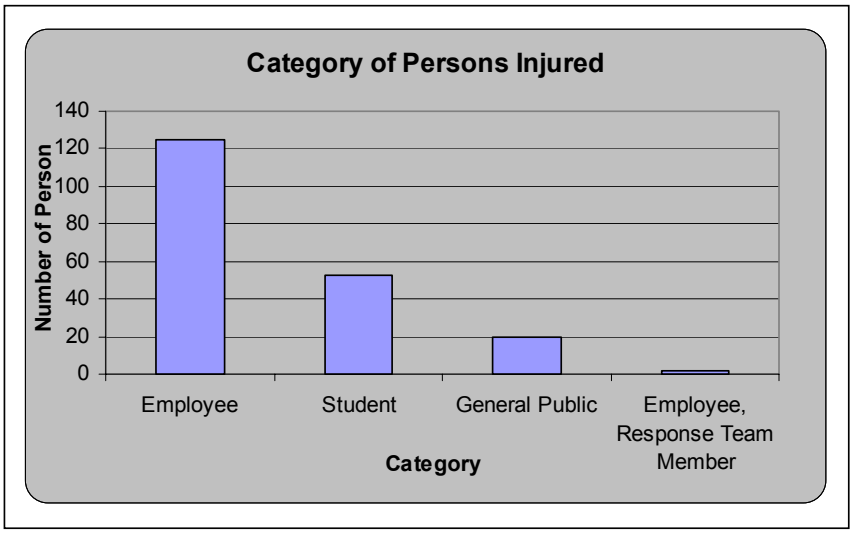

Figure 3.18: Category of Person Injured in Hazardous Materials Releases

The majority of hazardous material facilities are concentrated along the shoreline of the Columbia River. Significant areas that may be impacted are the Columbia River Fish and Wildlife Habitat, Lake Vancouver Wetland Area and the Ridgefield Wildlife Refuge.

Several schools and nursing homes are spread throughout Clark County, but are concentrated near industrial facilities and transportation routes. Additionally, a significant amount of the population is concentrated around these areas and would be affected by a hazardous materials incident near the industrial areas.

Capabilities

The following is a list of programs and requirements that are already in place that can help to reduce the risk of hazardous material incidents.

Vancouver Fire Hazardous Material Team. This team is the first responder to all hazardous materials incidents.

Local Emergency Planning Committee (LEPC) – The LEPC is required by SARA and made up of members of the community for the purpose of providing community guidance on hazardous material incidents, emergency response, preparedness and planning. LEPCs develop emergency plans, collect chemical storage information (Tier II reports), review toxic release inventory reports, and enhance public awareness of hazardous materials.

Hazardous Materials Emergency Response Plan - The plan addresses hazardous materials emergencies and disaster incidents, and provides guidance for preparedness, response and recovery operations. The plan is designed to quickly assess the type, nature and extent of a release and distribute the information concerning the incident to the public.

Federal Grants - The Hazardous Materials Emergency Preparedness (HMEP) grant program provides financial and technical assistance and guidance to enhance State, Territorial, Tribal, and local hazardous materials emergency planning and training. It distributes fees collected from shippers and carriers of hazardous materials to emergency responders for hazmat training and to LEPCs for hazmat planning. Washington State received $206,220 for the year of 2003.

Mutual Aid Agreements[5] – Several mutual aid agreements have been made throughout Clark County with various organizations.

- Clark Regional Emergency Services Agency *Interlocal Cooperation Agreement.*
- Hazardous Materials Incident Assistance Agreement, August 1, 1988. Clark County Fire Protection District No. 5, Clark County, municipal corporations and participating agencies.
- "RE: Hazardous Materials Incidents Assistance". **Vancouver Fire Department Letter: dated July 2, 2001.**
- See also: Direction and Control, Designation of incident command agency.
- Georgia Pacific Mill Emergency Response Team (MERT), *Agreements for Mutual Aid*
    - City of Camas Fire Department, dated August 21, 1998
    - City of Washougal Fire Department, dated January 1, 1996
    - Clark County Fire Protection District #1, dated September 20,1995
    - Clark County Fire Protection District #9, dated February 12, 1998
    - *Permit Number SW-147*, State of Washington, Department of Natural Resources, November 4, 1997
    - Integrated Contingency Plan/ Emergency Response Plan, approved by WASHDOT, WISHA, OSHA, EPA, and Ecology.

Shelter-in-place - This is a plan made for the community when emergencies such as de hazardous materials releases or incidents affecting air quality occur. Clark County uses the Emergency Alert System to inform the public using the media or police and fire personnel or a siren that an incident has taken place.

Hazardous Material Information – Hazardous Material Information can be found through several governmental agencies websites.

- FEMA provides information on their website: http://www.fema.gov/hazards/hazardousmaterials/
- Clark County LEPC - http://www.co.clark.wa.us/emergency/lepc/LEPCwhat.htm

Scenario

As growth continues in Clark County, residential and commercial development will continue to increase. With new commercial development, there is a potential for an increase in hazardous material facilities, escalating the chances for hazardous material incidents. A most probable and realistic event will be a Cascadia Region Subduction Zone Earthquake of magnitude 8.5. The ground-shaking caused by the earthquake would damage older structures that have not been retrofitted located on NEHRP soils types D, E and F. This would considerably affect areas such as the Port of Vancouver and Camas/Washougal. Liquefaction in these areas is also a possibility. This could result in structural failures of facilities. Several facilities located in these areas contain or use hazardous materials.

Impacts of an event like this would include spills or releases particularly from facilities that are in the industrial areas of Vancouver, Camas and Washougal that are constructed on softer soils. With the release, conflagration could take place creating both hazardous materials and fire hazards for the surrounding community and environment. Spread of fire within the port areas will be a major concern because of limited ingress and egress to the site for response vehicles and employees. This will cause problems of isolation for employees and may likely prevent effective containment of the fire or hazardous material release.

Long-term, this event will affect environment and regional economy. Hazardous materials released into the Columbia River would have a considerable affect on fish and estuarine habitat. The Vancouver Lake Wetland Area would likely be damaged and the possibility of hazardous materials spreading towards the Ridgefield Wildlife Refuge is likely. Clean-up efforts with the ports as well as the surrounding environment would be costly and time consuming. The Port of Vancouver is a major economic center for this region. Damages from a hazardous material release and fire these could be a severe negative impact.

Loss Estimation

Loss from exposure to hazardous materials in Clark County is nearly impossible to calculate without the completion of technical studies on each Tier II reporter. Clark County has a wide array of chemicals, each of which has its own properties and effects when released. Extents of release and affected areas are also often dependent on weather conditions such as wind and rain. Some hazardous materials, when released, would result in no loss to property and very little clean up expenditure (a loss estimate very near to $0), while others would result in loss of life in surrounding neighborhoods, expensive emergency response and clean-up figures ranging from hundreds to thousands of dollars.

Given this variety, it is difficult to assess exposure to hazardous material spills with enough specificity to allow loss estimation.

[1] Washington Military Department; Emergency Management Division. ***Washington State Hazard Identification and Vulnerability Assessment.*** 2001.

[2] WAC Chapter 118-40. Section 311(e) of Title III

[3] http://www.atsdr.cdc.gov/HS/HSEES/annual97.html#exsumm

[4] Clark County Emergency Service. ***Hazardous Material Commodity Flow Study***. September 30, 1998.

[5] Clark County LEPC. ***Draft Hazardous Materials Emergency Response Plan*** (HMERP); May 10, 2002

Chapter 3f
Landslides

Definitions

Landslide

Landslides can be described as the sliding movement of masses of loosened rock and soil down a hillside or slope. Fundamentally, slope failures occur when the strength of the soils forming the slope exceeds the pressure, such as weight or saturation, acting upon them.

Rotational-Translational slides

A type of landslide characterized by the deep failure of slopes, resulting in the flow of large amounts of soil and rock. In general, they occur in cohesive slides masses and are usually saturated clayey soils.

Rock falls

A type of landslide that typically occurs on rock slopes greater than 40% near ridge crests, artificially cut slopes and slopes undercut by active erosion.[1]

Earthflows

Earthflows are slow to rapid down slope movements of saturated clay-rich soils. This type of landslide typically occurs on gentle to moderate slopes but can occur on steeper slopes especially after vegetation removal.

Debris Slides

Debris slides consist of unconsolidated rock or soil that have moved rapidly down slope. They occur on slopes greater than 65%.

Figures 3.19 and 3.20 display shallow and large landslides.

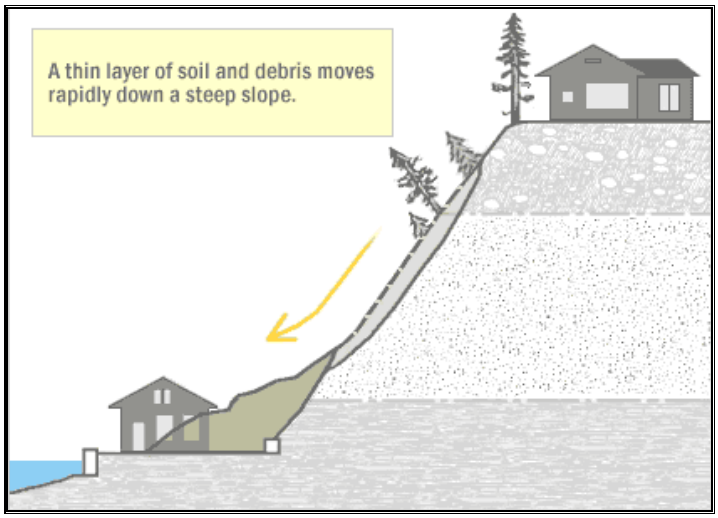

Figure 3.19: Shallow Landslide

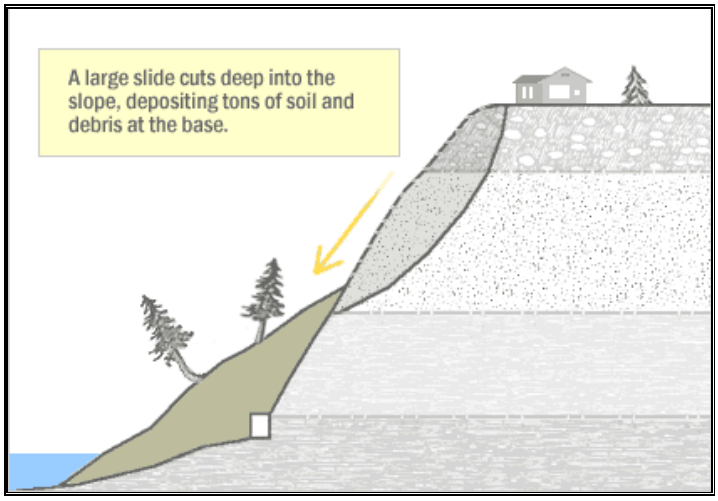

Figure 3.20: Large Landslide

Background, Landslides

Clark County is topographically level to gently rolling in the southwestern areas, while the eastern and northern areas of the county contain steep, forested foothills and mountains of the Cascade Range. The elevation ranges from sea level to over 3500 feet in the foothills in the eastern portion of the county. Historically, Clark County has experienced landslides occurring as a result of slope instability, foundation distress, poor drainage and excessive.[2] Landslides have become more predominant in recent years and may be attributed to the rapid population growth and development combined with the intense rainfall and storms that occur in this area.

It is important to understand the link between the development of roads, houses, buildings or other infrastructure and landslides events. Excavation and the removal of vegetation often destabilizes slopes by either directly changing the natural repose of a slope or by redirecting or stopping water drainage. These can potentially cause the soil on the slope to become saturated. As a result, landslides can occur on water saturated slopes when the base of the slope can no longer support the weight of the soil above it. Soil composition is also a factor, with many slides occurring on a slope at the contact between a permeable soil such as sand and an underlying impervious material such as clay. The Missoula flood deposits over much of central Clark County are characterized by alternating sand and clay layers.

Historic landslide areas are more susceptible to construction-triggered sliding than are undisturbed slopes. Construction affected slopes combined with a severe storm may also potentially result in landslides

Landslides Hazard in Clark County

Clark County has several areas where landslides have occurred, as well as areas that have the potential for future landslides. During 1996 and 1997, several landslides occurred as a result of heavy storms and flooding. One particular landslide occurred near Jenny Creek in Northwest Clark County. Other landslides in this area have occurred but have been repaired using various engineering techniques. Currently, the most susceptible locations are areas in La Center and Ridgefield and on the steep slopes north of Camas and Washougal.[3]

In Clark County landslides occur as a secondary hazard to heavy rain and winter storms and as a result of new development. They also can be secondary hazards to wildfires that clear slopes of vegetation thereby creating greater exposure to severe storms. Such landslides can occur several years after the fire. Landslides can also be a secondary hazard to earthquakes; however geologists agree that large rotational landslides are not likely to occur as a result of a major earthquake in Clark County. It is likely, however, that shallow debris slides could occur after a quake.[4]

Clark County GIS and Assessment have developed a map combining steep slopes with historic landslides and debris flow areas throughout the county. Figure 3.21 the current landslide potential and historic landslide locations. Several of steep slopes are found in northwestern Clark County mainly in or just outside of the Ridgefield and La Center areas. There are also steep slopes of concern in Camas and Washougal.

The most significant landslides occur in Clark County after inclement weather such as heavy rain and winter storms. Rock and soils on steep slopes are weakened by saturation from snowmelt and heavy rain creating stresses on the slope that eventually cause destabilization of the slope. Another concern in the county is historical landslides. Ancient dormant slide masses that have occurred throughout the county can be reactivated by severe winter storms. These are typically made up of broken materials and disrupted ground water.

Based on precipitation data from NOAA, weather threshold rainfall markers were developed for Clark County. The threshold rainfall markers are shown in Table 3.18. This means that if one inch of rain fell in the Vancouver area over 6 hours, there is a greater possibility of landslides occurring. Threshold rainfall markers provide general guidance on determining landslide activity.[5]

Weather Station	Thresholds Rainfall (inches) *6 hours*	*12 hours*	*24 hours*
Vancouver	1	1.5	2.5
Merwin Dam	5	3	2

Table 3.18: Rainfall Threshold Information

Landslides in the county have generally ranged in size from thin masses of soil that are a few yards wide to deep-seated bedrock slides more than six miles across. In 1997, one major landslide 2 miles north of Woodland (outside of Clark County) occurred in which 32,000 cubic yards of material fell across all lanes of I-5, blocking traffic for several hours. The velocity of landslide vary widely, but typically will range from a few inches per month to many feet per second, depending largely on slope, material, and water content. Landslides in the county are typically not sudden releases of material and are a function of saturation from heavy rain and snowmelt.

Anecdotally, landslides have not caused loss of life in Clark County, and few have resulted in the loss of property. On December 23, 2002, one landslide blocked a portion of the Washougal River Road, producing traffic problems.

Sometimes, signs of movement are evident prior to a landslide. These include benches, scarps, and large cracks in the landscape, sagging or taut utility lines, cracks in walls and window corners and tilted trees. In addition to this, there may be small ponds of water on an otherwise sloping terrain and unusually heavy and muddy seepage.

Secondary Hazards

Landslides can typically cause several different types of secondary effects. Several landslides have blocked egress and ingress on roads. This has the potential to cause isolation for affected residents and businesses. Roadway blockages caused by landslides can also create traffic problems resulting in delays for commercial, public and private transportation. This could result in economic losses for businesses.

Other potential problems resulting from landslides are power and communication failures. Vegetation on slopes or slopes supporting poles can be knocked over resulting in possible losses to power and communication lines. This, in turn, creates communication and power isolation. Landslides have the potential of destabilizing the foundation of structures that may result in monetary loss for residents.

It is possible for landslides to affect environmental processes. Landslides can damage rivers or streams, potentially harming water quality, fisheries and spawning habitat.

Vulnerabilities

In Clark County, the main concern with landslides is the blockage of ingress and egress on roads and destruction to property. As Clark County continues to experience a rapid residential growth rate, more homes and businesses may be constructed in areas vulnerable to landslides. Many of these areas are in Camas, Washougal, Ridgefield and La Center. Landslide hazard areas defined by the County Code are as follows[6]:

- Areas of previous slope failures including areas of unstable old or recent landslides;
- Areas with all three of the following characteristics:
    - Slopes steeper than 15%

- Hillsides intersecting geologic contacts with permeable sediment overlying a low permeability sediment or bedrock, and
- Any springs or groundwater seepage

- Slopes that are parallel or sub-parallel to planes of weakness, such as bedding planes, joint systems and fault planes in subsurface materials;
- Slopes greater than 80%, subject to rock fall during earthquake shaking
- Areas potentially unstable as a result of rapid stream incision, stream bank erosion, and stream undercutting the toe of a slope
- Areas located in a canyon or on an active alluvial fan, presently or potentially subject to inundation by debris flows, debris torrents or catastrophic flooding
- Areas adjacent to open-pit mine sites subject to steep slope hazard or landslide hazard

Steep Slope Hazard Areas are defined in the Clark County Code as follows:

- An area where there is not a mapped or designated landslide hazard, but there are steep slopes equal to or greater than 40% slope.
- Steep slopes which are less than ten feet in vertical height and not part of a larger steep slope system, and steep slopes created through previous legal grading activity are not regulated steep slope hazard areas

Homes and property susceptible to landslides usually are located in or near historic and potential landslide areas and historic debris fall areas and are vulnerable to damage. A GIS assessment has been undertaken to determine the number of parcels in Clark County that are susceptible to landslide hazards. A buffer of 100-feet was placed around historic and potential landslide areas and debris fall areas, and the number of parcels within the buffer was calculated. Figure 3.22 shows the distribution of landslide susceptible parcels by city.

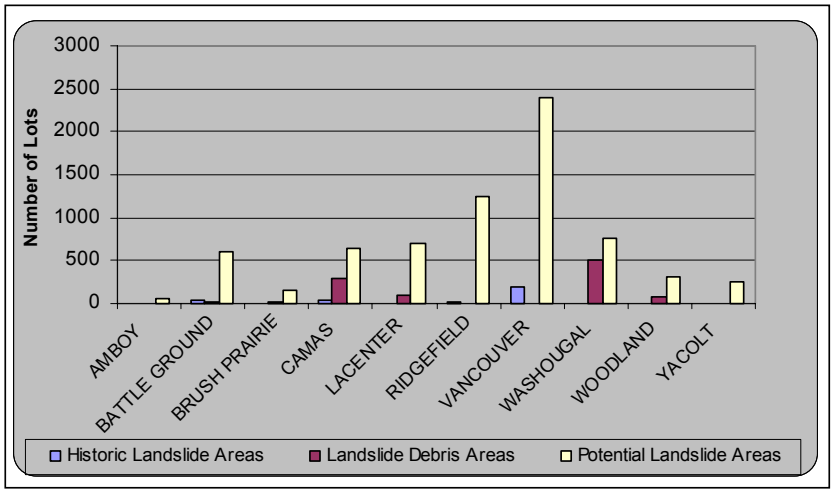

Figure 3.22 - Landslide Hazards by City

Included in this analysis is the number of lots that could be developed in the future. These lots vary in size but generally fall within the 5 to 10 acre range. Table 3.19 shows the number of developed, developable and undevelopable lots located in or around the landslide hazard areas.

Level of Development	Historic Landslide Areas	Landslide Debris Areas	Potential Landslide Areas
Developed	231	637	5024
Developable	41	295	1937
Undevelopable	14	91	189
Total	**286**	**1023**	**7150**

Table 3.19: Development of Lots in Landslide Hazard Areas

Several parcels that are developable are zoned for commercial or residential development. This means that rapid growth and development is continuing in the county with the potential for growth in areas prone to landslide hazards.

Isolation poses a problem for new developments in Clark County. Protecting roads from hazards becomes particularly important in situations where they provide the only route into and out of an area. Some such roads occur in developments in Camas, Washougal, Ridgefield and La Center.

The Burlington Northern, Santa Fe and the Lewis and Clark Railways extend throughout the county. The Burlington Northern Railway passes through Ridgefield along a slope currently classified as potentially unstable. Additionally, the Lewis and Clark Railway passes between Battleground and Yacolt in an area that is classified as a slope of potential instability. The Santa Fe Railway also passes along dangerous slopes in Camas and Washougal, as well as areas where old landslide debris was located.

Two schools located in Ridgefield and La Center are near areas of older landslide debris and slopes with potential instability and could be potential concerns. These are near roads and have the potential to cause isolation for students and parents.

Code Requirements

Clark County Municipal Code requires that developments and construction follow certain guidelines that help to locate development in areas safe from potential geologic hazards. The County Code designates 'Landslide Protection Areas' which provide development regulations for steep slope hazard areas to prevent potential landslide damage. Developing and improving land away from steep slopes and leaving steep slopes in natural vegetation are encouraged in the code. Development in landslide hazard areas is generally not allowed. To minimize risks, the code requires buffers and setbacks and that keep vegetation in a natural state on and around the landslide hazard area. Additional requirements for steep slope and landslide hazards areas are provided in the Erosion Control Ordinance of the Clark County Code.[7]

The code for landslide and steep slope hazard areas requires developments to have:[8]

- Steep Slopes - Mapping of slopes greater than 40 %
- Steep Slopes - Setbacks and buffers for development occurring on base and top of slope
    - Distances must be based on percentage of slope
- Landslides - A minimum buffer of 50-feet
- Landslide Protection Areas – applies only to site plans and land divisions
- Clearing or vegetation removal in landslide protection areas, steep slope hazard areas or landslide hazard areas or their buffers is prohibited

Capabilities

The following provides a list of programs and requirements already in place that can help to reduce the risk from landslide and steep slope hazards in Clark County.

Clark County Geological Hazard Areas Regulation - Based on the Growth Management Act, the Geologic Hazard Areas Regulation was adopted in 1997 under Ordinance 1997-05-34 (Title 13.60).

Erosion Control Certification Course - Clark County Code 13.29.430 Contractor Certification. Starting January 1, 2001, development activities performed by licensed contractors must be supervised by an individual who must have successfully completed formal training in erosion and sediment control during construction by a recognized and acceptable organization. A certification of successful completion of such training must be submitted at the pre-construction conference. This does not apply to residential homeowners constructing their own dwellings.

Erosion Control Program - Launched in 1998, the program encompasses new development, capital construction and operations and maintenance activities. This program includes the following elements:

- Outreach efforts inform and involve the community in program development
- Research into other programs gives insight into what works well
- Internal coordination keeps staff informed and provides a feedback loop for further improvements
- Education and technical assistance efforts ensure that staff, the development community and the public are aware of erosion control requirements and best management practices
- Defining and implementing new processes promotes consistency in inspection and enforcement activities. Monitoring program activities allows us evaluate program effectiveness over time
- As an incentive to compliance the county is developing a recognition program for those demonstrating excellence in controlling erosion

Landslide Risk Reduction Information – Landslide Risk Reduction Programs are available through government agencies via their websites.

- The Washington Department of Ecology provides information on landslides in addition to measures to prevent landslides
- The USGS has a National Landslides hazard Program that provides information and mitigation on http://landslides.usgs.gov/

Clark County Outreach Programs –

- Project Impact Community – institutes outreach programs within the community
- Neighborhood associations are spread throughout the county and deal with several different issues including development issues. As of now, most are located away from city centers, in areas that development is occurring.
- Clark County has a Conservation District Office (360 696-7631) that helps with land management issues. (http://clark.scc.wa.gov/)
- Washington State University Cooperative Extension (360 254-8436) that helps community members improve quality of life. (http://clark.wsu.edu/index.html)

Support following a presidential declaration - There is considerable support for risk reduction measures following a federal declaration. Often these programs and their implications are not taken advantage of before permanent repairs are made. Some of the more significant ones include:

- The Hazard Mitigation Grant Program (HMGP) offers assistance for a wide range of mitigation projects following a presidential declaration. Eligibility is restricted to projects have gone through a comprehensive hazard mitigation planning process
- Minimal Repair Program often funds risk reduction by replacing damaged materials with fire resistant replacements
- The Small Business Administration will fund eligible mitigation measure to qualified owners of damaged homes
- Outreach is available through Disaster Reconstruction Assistance Centers (DRACs), Recovery Information Centers or Hazard Mitigation Teams
- Benefit/Costs Mitigation support is available from FEMA on Infrastructure repair. To break the damage-rebuild-damage cycle FEMA Region 10 is encouraging communities to:
    - Institute, mitigation betterments taking advantage of multi-hazard, multi objective approach when ever possible
    - To strengthen existing infrastructure and facilities to more effectively withstand the nest disaster
    - To ensure that communities address natural hazards through comprehensive planning

Scenario

Landslides are becoming more of a concern as development moves outside of city centers and into areas less developed in terms of infrastructure. Major landslides in Clark County occur as a result of soil conditions that have been affected by severe storms, groundwater or human development activities. After heavy rains during from January to March, soils become saturated with water. As water seeps downward through upper soils that may consist of permeable sands and gravels and accumulates on impermeable silt, it will subsequently cause weakness and destabilization in the slope. In addition, as rains continue, the groundwater table rises adding to the weakening of the slope. Gravity, poor drainage, a rising groundwater table and poor soil exacerbate landslide conditions.

The worst-case scenario for landslide hazards in Clark County would generally correspond with a severe storm that had heavy rain and caused flooding events. Because landslides typically transpire in more sparsely developed areas of the County, it is probable that infrastructure in these areas will be affected.

Road obstructions caused by landslides would most likely occur and create isolation problems for residents and businesses in the more sparsely developed areas. It is also likely that property owners located on steep slopes may suffer damages to either the property or the structure itself. In addition to this, landslides carrying vegetation such as shrubs and trees may also cause a break in power or communication lines cutting off power and communication access to residents.

Continued heavy rains and flooding will complicate this problem further. As resources within Clark County attend to problems with flooding, it is possible they may be unavailable to assist with landslides occurring all over Clark County. This will worsen the problem of isolation for residents and business.

It is likely that landslides will occur anywhere in the county that have been affected by historic landslides and areas that have potential steep slopes but a most likely landslide event would occur in either the La Center and Ridgefield area or the Camas and Washougal area. This is based on historical events and steep slopes with a potential for instability.

Loss Estimation

Loss Summary	
Residential exposure:	$811,657,800
Residential exposure possible given growth potential:	$1,681,257,600
Lives affected:	13,476
Economic loss:	Difficult to calculate; includes immediate damage to commercial and industrial properties (279 exposed lots), damage to utilities (electrical lines, reservoirs, etc.), loss of revenue from workers unable to work, clean-up expenses (clearing roads, etc.), and potentially the loss of developable lands.

Table 3.20: Estimated Losses in Clark County from Landslide

The loss calculations above use Clark County's map of historic landslides, debris fall areas, and potential landslide areas as the basis of analysis. As it is extremely unlikely that all potential landslide areas would experience slippage at the same time, this figure really represents the dollar value of the residential property exposed to the hazard.

Residential exposure numbers were calculated by considering all parcels that intersect the mapped landslide hazard areas (5183 parcels) and multiplying that number by the average cost of a home in Clark County ($156,600[9]). While each of these parcels is susceptible to possible landslides, the figures above likely represent an overestimate. For many of these parcels, the actual structures might be distant enough from the landslide hazard that an event would affect the parcels but not the home itself. Losses given growth potential were calculated based on the number of buildable lots plus the number of currently developed lots in landslide susceptible areas.

Generally speaking, lives are not often in danger from landslides. Many landslides move slowly, providing ample warning time for evacuation. However, they can be very destructive, causing hardship for those in their proximity. The 'lives affected' number above was calculated by multiplying the number of residential parcels in landslide prone areas by the average number of people per household in Clark County (2.6[10]).

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[1] Dames & Moore. February 28, 2000. *Geotechnical Hazard Identification, Clark County Road System*. P. 1.

[2] *Ibid, p. 6*

[3] *ibid*., P. 6

[4] Steve Palmer. Washington State Department of Natural Resources.

[5] *ibid,* P.6

[6] Chapter 13.60.330, Landslide hazard areas, Clark County Code

[7] Chapter 13.29 STORMWATER AND EROSION CONTROL ORDINANCE

[8] Title 13 Public Works, 13.60.240 Permanent protection for geologic hazard areas and buffers

[9] U.S. Census Bureau, 2000.

[10] U.S. Census Bureau, 2000.

Chapter 3g
Volcanoes

Definitions

Stratovolcano

The volcanoes in the Cascade Range surrounding Clark County are all stratovolcanoes. They are typically steep-sided, symmetrical cones of large dimension built of alternating layers of lava flows, volcanic ash, cinders, blocks, and bombs and may rise as much as 8000 feet above their bases.[1]

Following is a list of the different types of hazards associated with Cascade Range volcanoes:

Pyroclastic Flows and Surges

Pyroclastic flows are avalanches of hot (570-1470° F), dry, volcanic rock fragments and gases that descend a volcano's flanks during eruptions at speeds ranging from 20 to more than 200 miles per hour.

Lava Flows

Lava flows are normally the least hazardous threat posed by volcanoes. Cascades volcanoes are normally associated with slow moving andesite or dacite lava.

Tephra

The ash and the large volcanic projectiles that erupt from a volcano into the atmosphere are called tephra. The largest fragments 2½ inches) fall back to the ground fairly near the vents, as close as a few feet and as far as 6 mi. The smallest rock fragments (ash) are composed of rock, minerals, and glass that are less than 1/8 inch in diameter. Tephra plume characteristics are affected by wind speed, particle size, and precipitation.

Lahars

Lahars are rapidly flowing mixtures of water and rock debris that originate from volcanoes. While lahars are most commonly associated with eruptions, heavy rains, debris accumulation, and even earthquakes may also trigger them. They may also be termed debris or mud flows.

Debris Avalanches

Volcanoes are prone to debris and mountain rock avalanches that can approach speeds of 100 mph.

Volcanic Gases

All active volcanoes emit gases. These gases may include steam, carbon dioxide, sulfur dioxide, hydrogen sulfide, hydrogen, and fluorine.

Background, Volcanoes

A volcano is a vent in the earth's crust through which molten rock, rock fragments, gases or ashes are ejected from the earth's interior. There are a wide variety of hazards related to volcanoes and volcanic eruptions. With volcanic eruptions, the hazards are distinguished by the different ways in which volcanic materials and other debris flow from the volcano.

Volcano Hazard in Clark County

Volcanoes in the Cascades erupt at a rate of 1 or 2 every 200 years. Seven volcanoes have erupted in the Cascades since the first U.S. Independence Day a little more than 200 years ago. There are 20 volcanoes in the Cascades, but of these only Mounts Rainier, Baker, Hood, St. Helens, and Glacier Peak have been active in historical times. Mt. St. Helens is by far the most active volcano in the Cascades, with four major explosive eruptions in the last 515 years. The most famous of these occurred May 18, 1980. In this eruption, the elevation of Mt. Saint Helens dropped dramatically from 9,677 feet to 8,364 feet; 23 square miles of volcanic material buried the North Fork of the Toutle River to an average depth of 150 miles. A total of 57 human fatalities resulted from the blast.[2]

Constant monitoring of all active volcanoes means that there will be more than adequate time for evacuation before an event. Since 1980, the volcano has settled into a pattern of intermittent, moderate and generally nonexplosive activity, and the severity of tephra, explosions, and lava flows have diminished. All episodes, except for one very small event in 1984, have been successfully predicted several days to 3 weeks in advance. However, scientists remain uncertain as to whether the current cycle of explosivity has ended with the 1980 explosion. The possibility of further large-scale events continues for the foreseeable future.[3]

Despite its proximity to active stratovolcanoes Mt. Saint Helens (to the north) and Mt. Hood (to the south), Clark County has relatively low vulnerability to the direct effects of a volcanic eruption. The blast from a St. Helen's eruption is most likely to occur on the north face of the mountain, away from Clark County. An eruption from Mt. Hood is distant enough to have little effect on the county. However, some of the secondary effects, especially tephras (defined above) could be felt in the area.

All of Clark County is vulnerable to tephras to varying degrees, though prevailing easterly winds mean that most of the ash will likely accumulate in other areas. Most of Clark County has a 2% probability of seeing 4 inches or more ash accumulation from an explosion of Mt. Saint Helens. There is a 1% probability of a 4 inch tephra along the western edge of the county straddling the Columbia River.

In addition to tephras, Clark County has some vulnerability to lahars and mudflows. The Lewis River has a low vulnerability to the volcanic effects. The most susceptible areas would be Camas and Washougal along the Columbia River opposite the Sandy River. Here, a lahar resulting from a Mt. Hood eruption could inundate the Columbia River, forcing flood waters into the area surrounding the Port of Camas and Washougal. The threatened area includes the Lady and Reed islands plus the lowland areas to the north and south of SR-14 in the Camas-Washougal Area.

Additionally, any eruption would have regional effects on the movement of traffic along major auto, rail, and shipping routes, along with a potential short-term economic slow-down that would be felt by residents of Clark County.

Vulnerabilities

Clark County has low vulnerability to volcanic hazards. Lahars and tephras can potentially cause the most damage:

- In Clark County, the major lahar threat is sudden flooding along the northern bank of the Columbia River as described above.
- Most of the County has some susceptibility to tephra. Ash only ½ inch thick can impede the movement of most vehicles and disrupt transportation, communication, and utility systems. Tephra may cause eye and respiratory problems, particularly for those with existing medical conditions. Ash may also clog ventilation systems and other machinery. When tephra is mixed with rain it becomes a much greater nuisance because wet ash is much heavier, more difficult to remove, and can even cause structures to collapse. Wet ash may also cause electrical shorts. Ash fall also decreases visibility and may cause psychological stress and panic. Figure 3.23 below depicts the probability of ash accumulation. As is evident, there is little likelihood of major accumulation, but some should be expected.

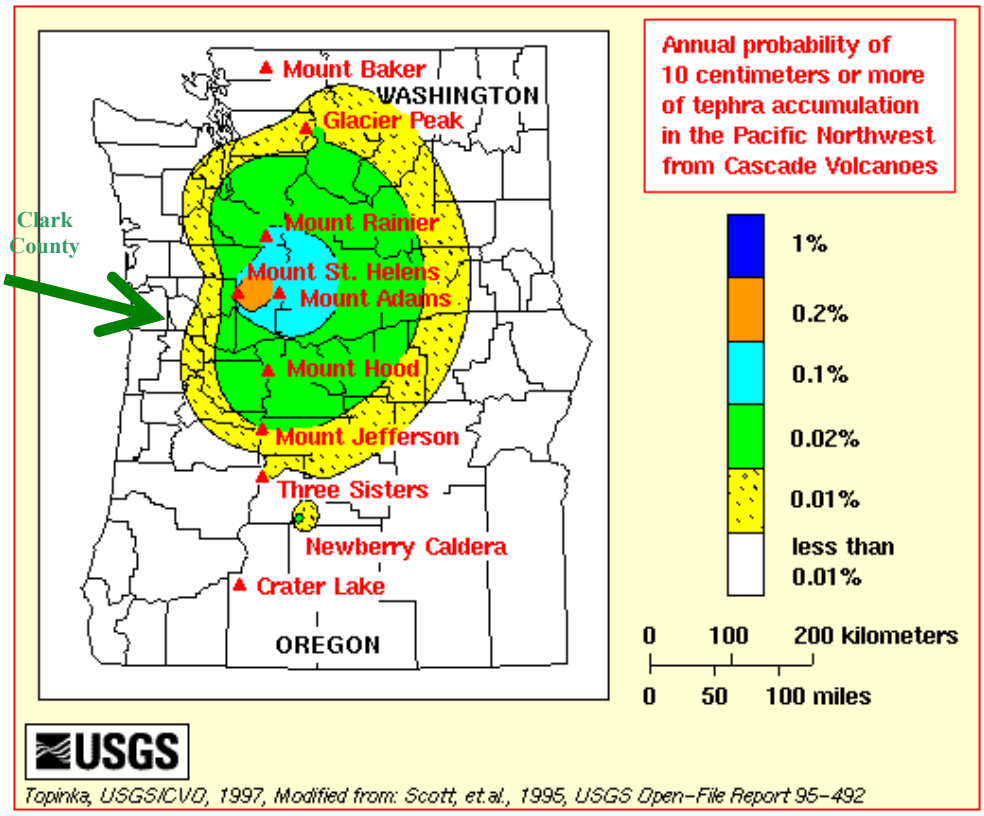

Figure 3.23: Probability of Tephra Accumulation from a Mount St. Helens Eruption[4]

Capabilities

Due to active monitoring of volcanoes in the Cascade Mountain region, an eruption is unlikely to occur as a surprise. Human life should be adequately protected from such an event.

Dikes and bulkheads along the north bank of the Columbia RIver could help to protect property from the effects of a lahar-induced flood.

Scenario

There are 2 probable volcanic events that have potential to affect Clark County. One would be an event similar to the 1980 eruption of Mt. Saint Helens. Such an event seems unlikely to directly impact the county, as the eruption would likely happen on the northern side of the volcano. However, depending on wind direction and velocity, ash could be an issue.

The other possibility is a Mt. Hood event, which could trigger a mudflow along the Hood River and into the Columbia below the Cascade Locks. This could cause flooding in Clark County along the Columbia River.

Loss Estimation

Loss figures resulting from volcano events in Clark County are difficult to calculate. As described above, the greatest damage from a Mt. Saint Helens eruption would most likely result from ash fall. This could result in indirect economic losses from workers unable to get to work and businesses closed during the period of clean up, and direct costs from the clean up itself. Those with respiratory illnesses might also feel some health effects from ash fall.

Additionally, some losses might result from flooding along the Columbia River resulting from a volcanic event at Mt. Hood. This would primarily affect the area around Camas and Washougal. In this area, there are 863 residential lots along the Columbia River and in the floodplains of the Columbia River's tributaries in those cities. It is likely that some of these lots would experience flooding, and in a worst-case scenario where all lots experience flooding, the resulting damage could reach $13,514,580[5]. This figure does not account for loss to commercial and industrial properties. There are 338 exposed properties, several of which are major employers for the county and the region.

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[1] USGS Cascade Volcano Observatory

[2] Brantley and Myers, 1997, Mount St. Helens -- From the 1980 Eruption to 1996: USGS Fact Sheet 070-97

[3] Tilling, Robert I., Lyn Topinka, and Donald Swanson. "Eruptions of Mt. Saint Helens: Past, Present and Future," USGS Special Interest Publication, 1990.

[4] Topinka USGSICVO, 1999, Modified from Scott, et al, 1995, USGS Open-file Report 95-492

[5] 863 affected parcels multiplied by the average cost of a home in Clark County, $156,600 (U.S. Census Bureau, 2000), and assuming a 10% loss of property value.

Chapter 3h
Terrorism

Background, Terrorism

Terrorist acts represent a growing concern for emergency management professionals. Clark County's Hazard Inventory Vulnerability Assessment (HIVA) cites the Federal Bureau of Investigation (FBI) definition of terrorism: "The unlawful use of force or violence against persons or property to intimidate or coerce a government, the civilian population, or any segment of it, in furtherance of political or social objectives."

The severity of terrorist attacks can be quite variable depending on the mode of attack, ranging from the simple nuisance of service disruption to massive loss of life and property. Biological or chemical attacks, nuclear or 'dirty bomb' events, and conventional bombings are all possibilities. Often, the psychological effects (feelings of increased vulnerability and decreased safety while going about every day events) are more significant than the actual event.

Again, the amount of warning that county officials might have to put emergency plans into place in the event of a terrorist attack is quite variable. Most events would occur with little or no warning time, making them quite difficult to defend against. Some biological events might give more lead-time for diagnosis and even potential vaccinations.

Terrorism Hazard in Clark County

As stated in its HIVA, Clark County has "no immunity to potential terrorist activity within its borders… Terrorist actions could be expected to come about as a result of grievances toward activities of some governmental entity, federal or state, or as retaliation for some governmental act..." Heightened alert as a result of the current international political situation cannot be ignored, as it raises the possibility of an attack regardless of location.

That said, the FBI has reported no terrorist events in the Clark County. The only two reported events in the State of Washington were bombings in Tacoma attributed to a Skinhead group. Insurance officials have recently ranked the City of Seattle among the top 10 potential terrorist targets in the United States, but Clark County is less likely to be the direct target of an attack. As stated in the HIVA, history suggests a low probability of occurrence. A moderate risk rating was assigned for terrorism.

Vulnerabilities

In most cases, the type of terrorist act will determine vulnerability. Vulnerabilities could include a large segment of the population or infrastructure, or just a few people and very little property. Damage could occur to man-made structures and systems, natural systems, and/or to human life.

Terrorist attacks can happen almost anywhere, but some facilities are more likely targets than other. These include:

- Highly visible or symbolic facilities, such as international corporate headquarters or government administration buildings
- High occupancy facilities, such as stadiums, airports, movie theaters, etc.
- Systems-related facilities, such as dams, water tanks, oil pipelines, electrical transfer stations, etc.
- Response facilities, such as police and fire stations
- Hazardous material storage sites, which have the potential to release toxins

In Clark County some potential targets might include the I-5 bridge, the Vancouver Port, sports stadiums, some dams, busy commercial areas, oil and water storage tanks, and electrical transfer stations.

As Vancouver is directly under the flight approach path for the Portland Airport, any incidents involving the downed planes could also affect Vancouver.

Nearby Portland also has many potential targets, and any large-scale events in Portland would inevitably affect Clark County both directly, as people cross the bridge to evacuate the city, and indirectly, as a result of economic changes in the region.

Scenarios

An event in any high occupancy facility or event could produce mass casualties, raise fear among citizens, and isolate segments of the city. Some examples might include:

- A terrorist attack during Vancouver's Fourth of July celebration, which draws between 80,000 and 100,000 people
- An attack that targets the I-5 bridge, which would create great economic difficulty for both Portland and Vancouver
- An attack at the Port of Vancouver, which has the potential to disrupt barge traffic as well as release hazardous materials into the Columbia River and surrounding residential areas

Additional scenarios that might affect Clark County are domestically based terrorist attacks "copy-catting" World Trade Center attacks or other well-known terrorist events.

Any large-scale terrorist attack targeting either Portland or the Puget Sound area would likely create havoc in Clark County as well, as emergency managers and responders struggle to deal with evacuees from these areas and the psychological effects of an attack near home.

Loss Estimation

Potential losses from terrorism range greatly depending on the type of attack that occurs. The World Trade Center attacks, for example, have an estimated loss figure of $2 billion[1]. Smaller-scale, more targeted attacks might have property damage figures below $10,000. As Clark County has had no past terrorist attack incidents, it is difficult to estimate the degree of damage possible. However, Table 3.21[2] provides the dollar value of some of the infrastructure and facilities that might be exposed to an attack, to provide a baseline for potential loss.

Facility	Dollar Value
Airport facilities and runways	$492,000,000
Ports	$13,500,000
Railway tunnels, bridges, and facilities	$27,000,000
Highway bridges	$950,000,000
Communication distribution lines	$84,339,000
Communication facilities	$26,000,000
Oil facilities	$6,000,000
Water water facilities	$420,000

Table 3.21: Dollar Value of Potential Terrorist Targets

In addition to any direct property loss that might result from a terrorist attack, indirect costs could also include psychological stress, loss of tourist income, job loss and/or loss of worker income and longer-term clean up projects.

[1] Congressional Budget Office Cost Estimate S. 1624, December 5, 2001

[2] HAZUS database, 1990

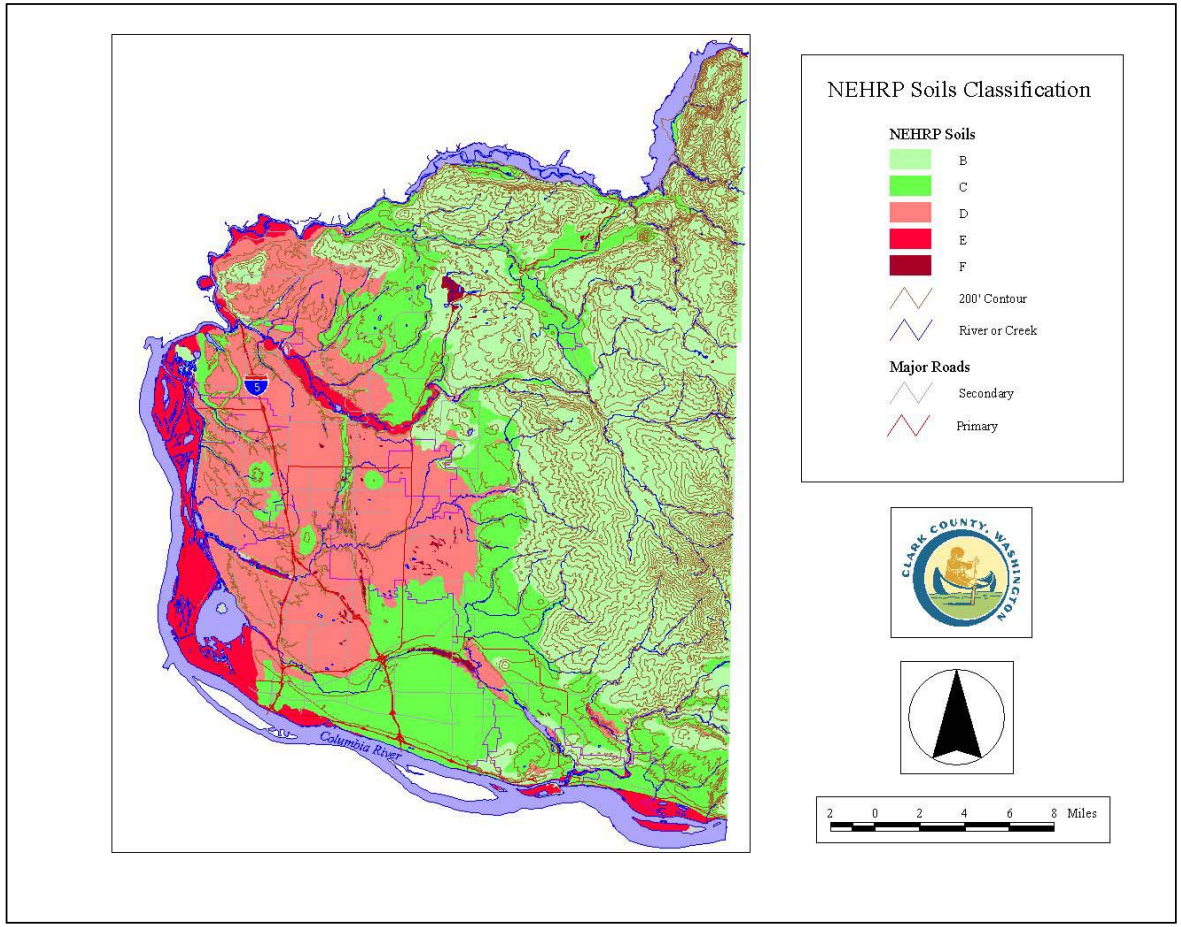

Figure 3.2: NEHRP Soils

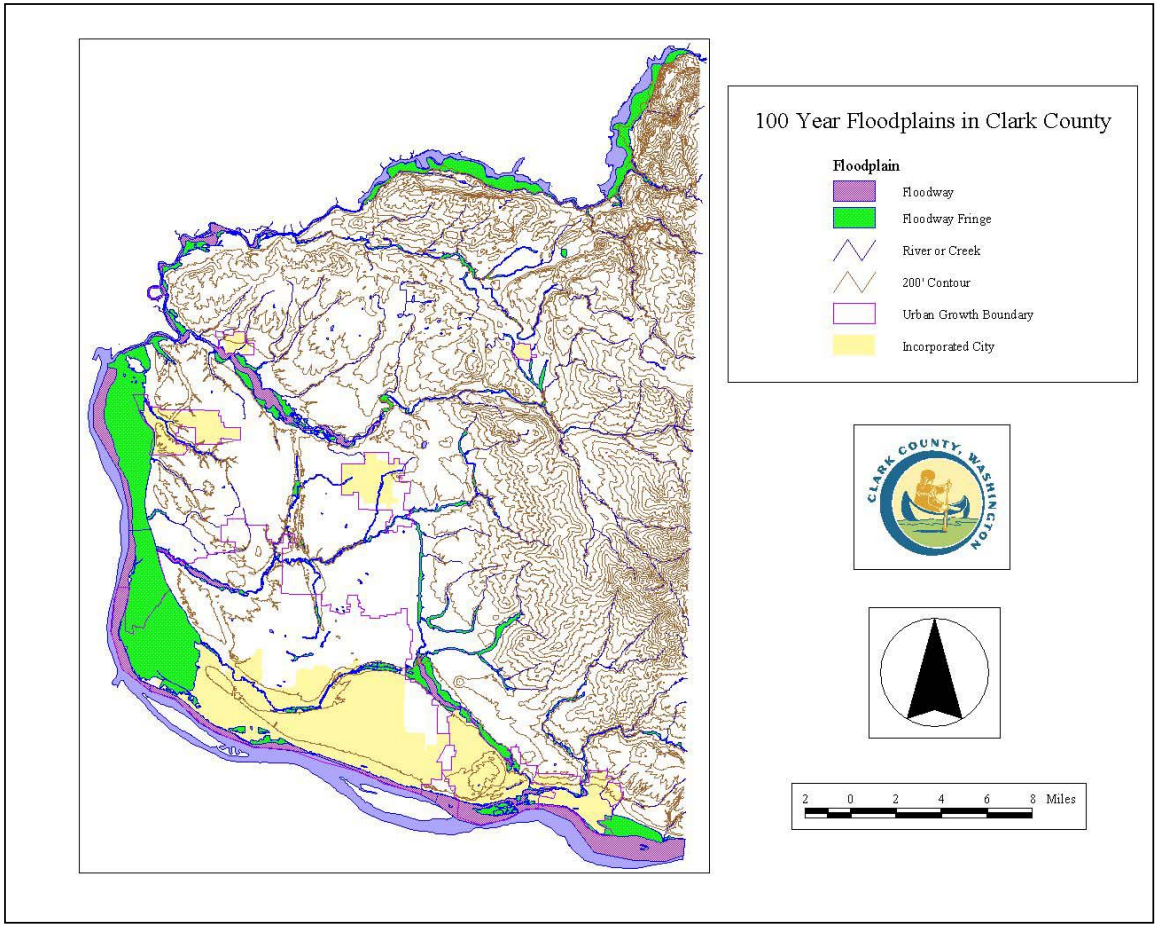

Figure 3.8: 100-Year Floodplain

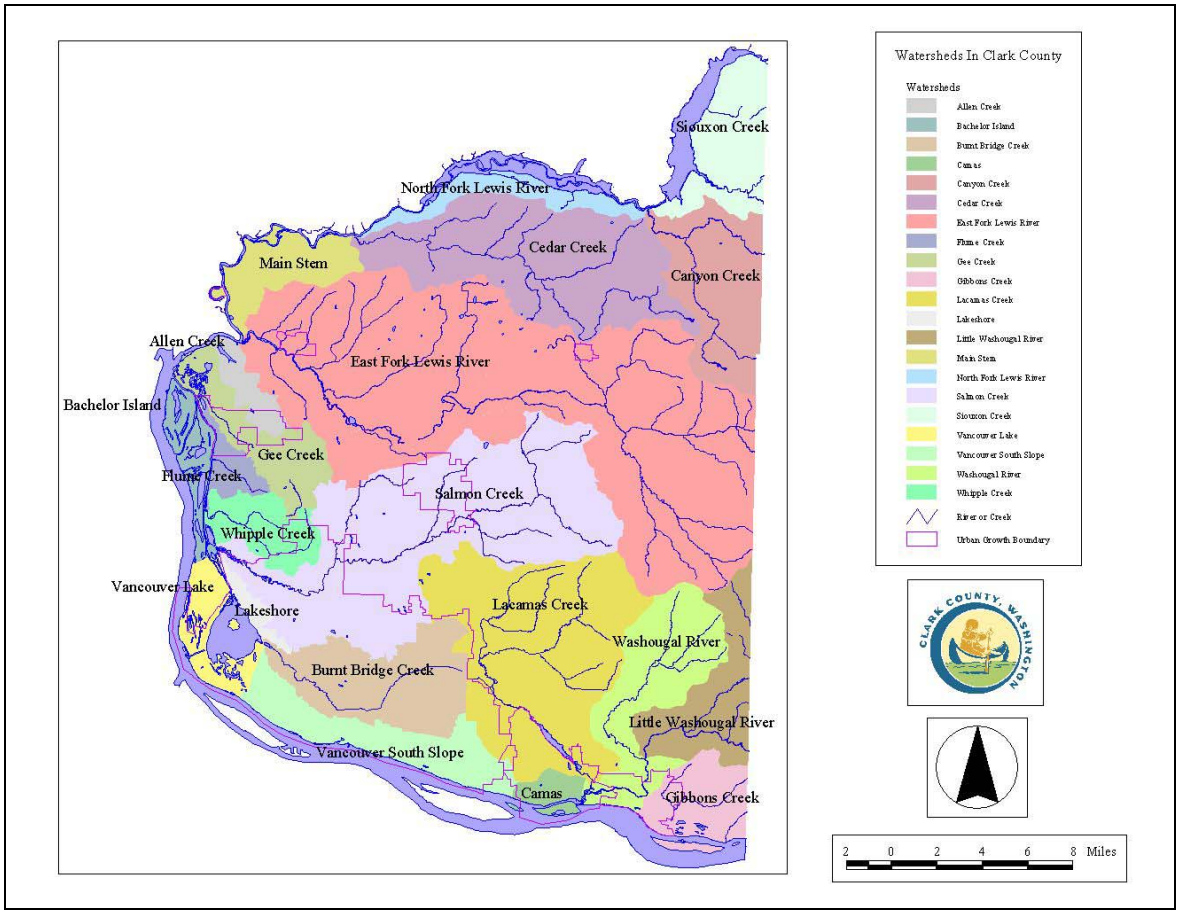

Figure 3.9: Watershed Boundaries

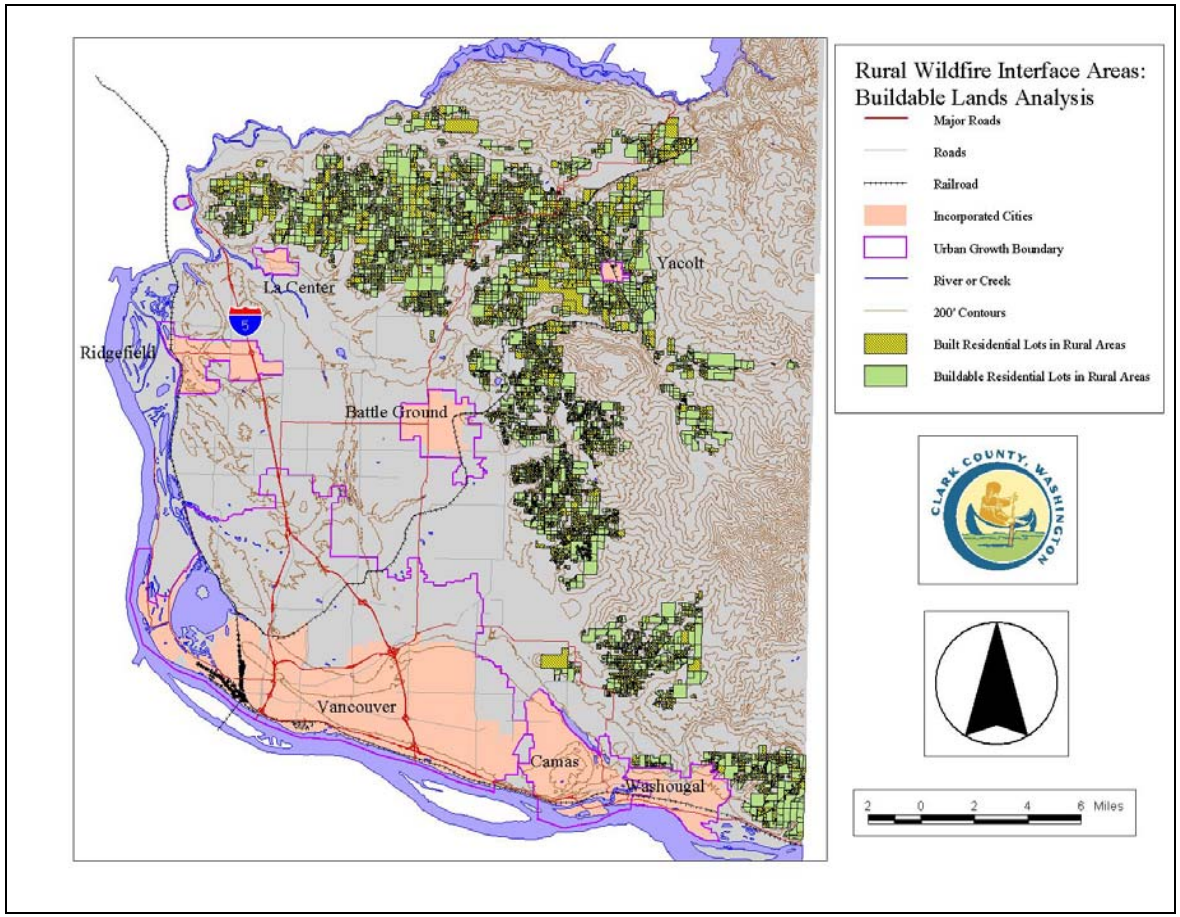

Figure 3.12: Rural Wildfire Intermix Area

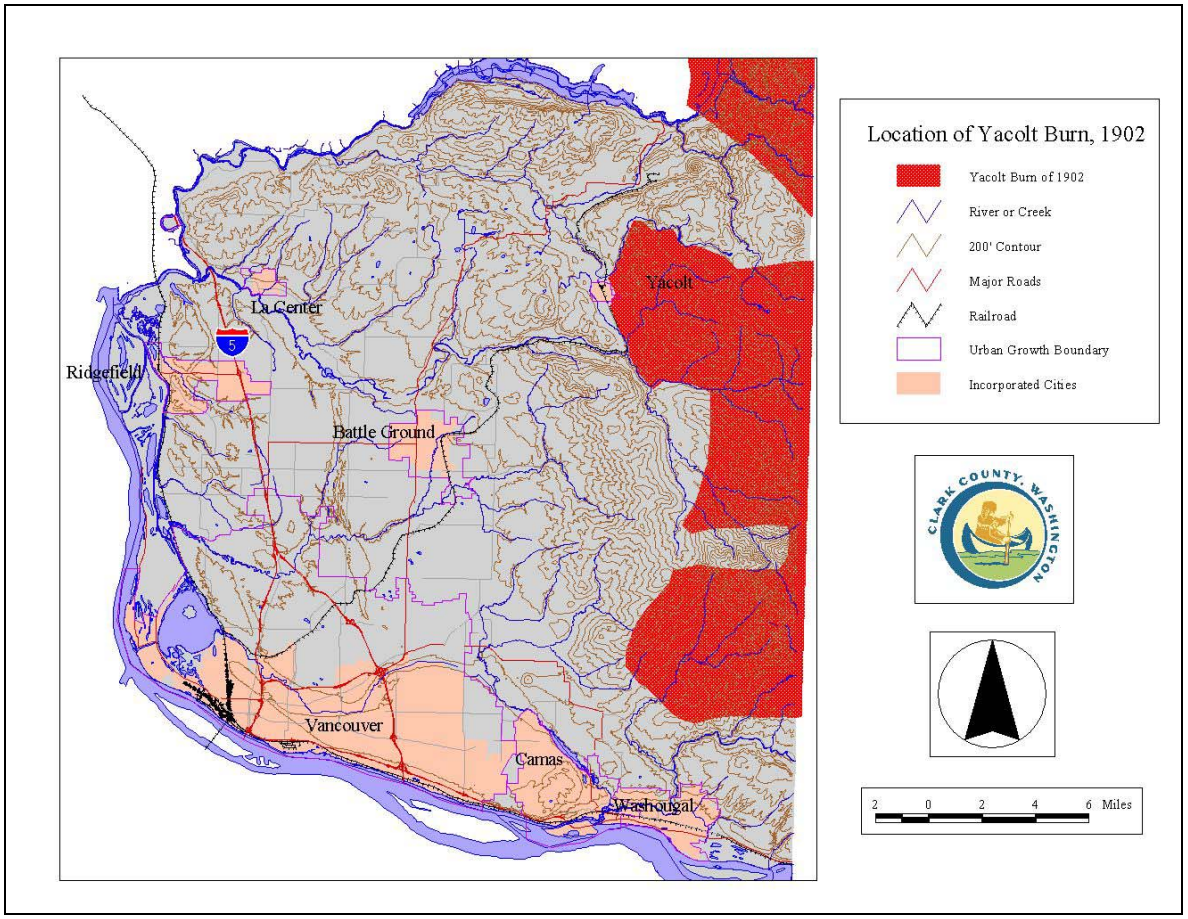

Figure 3.13: Yacolt Burn

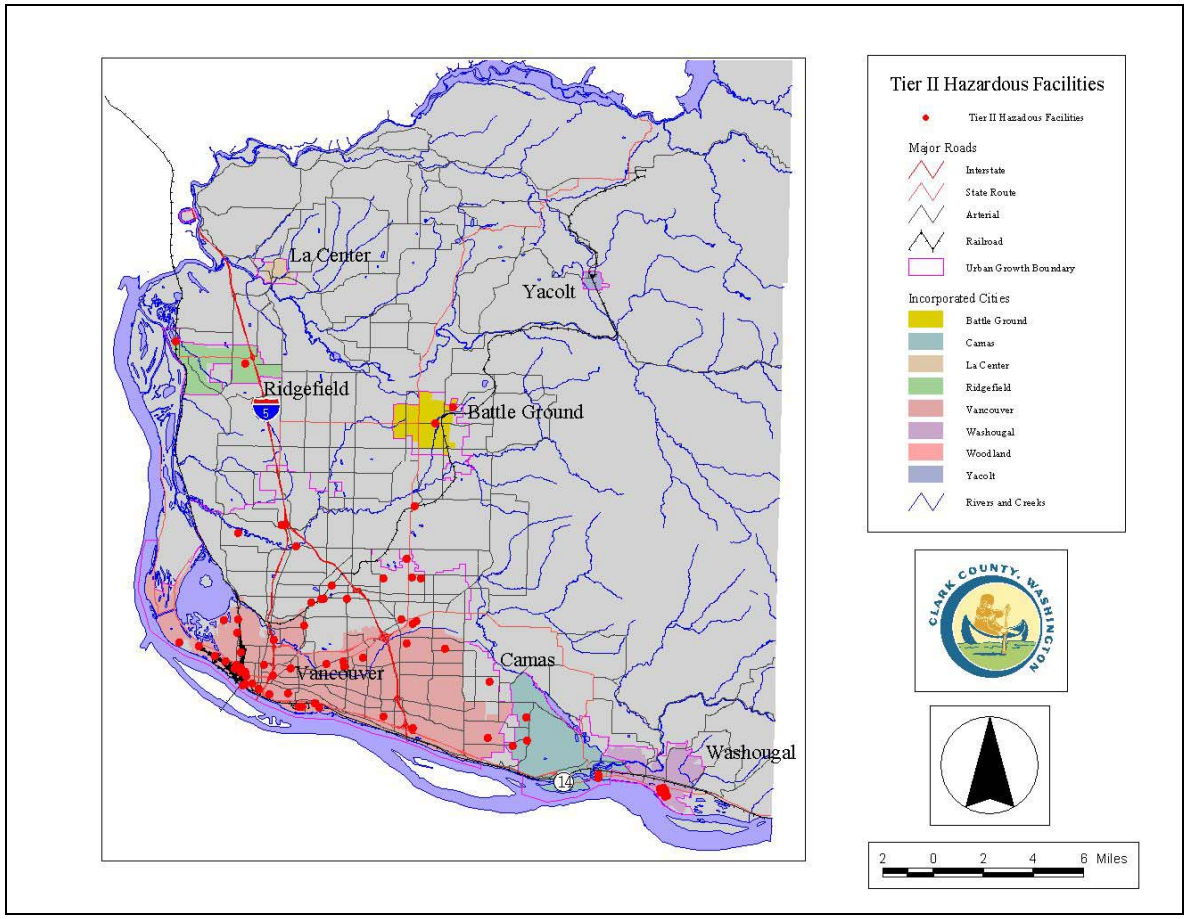

Figure 3.16: Tier II Hazardous Material Facilities

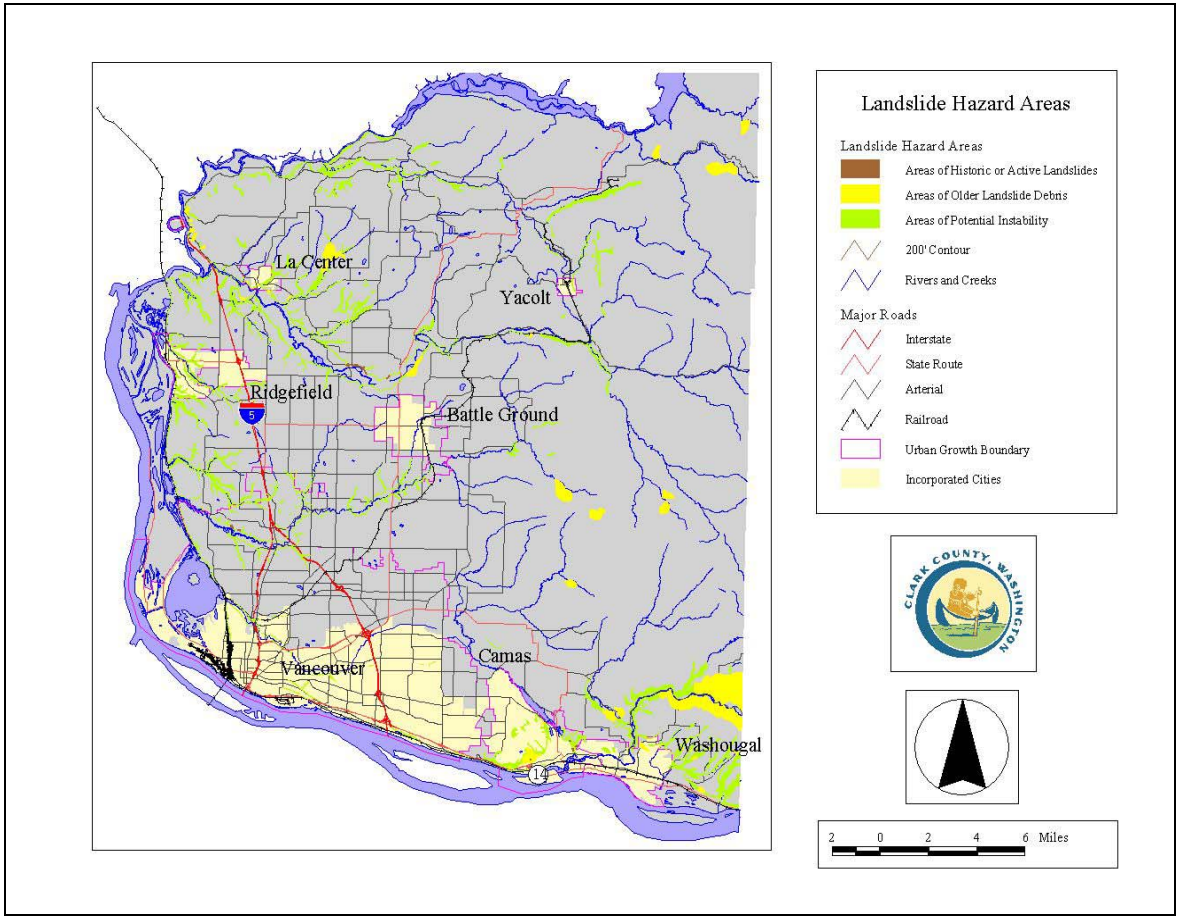

Figure 3.21: Landslide Hazard Areas